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A pre-COSEWIC assessment of the Common Lumpfish (*Cyclopterus lumpus*, Linnaeus 1758) in Canadian Atlantic and Arctic waters

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The Common Lumpfish (*Cyclopterus lumpus*, Linnaeus 1758) has been scheduled for assessment in November 2017 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), under the federal *Species at Risk Act* (SARA). The primary purpose of this paper is to provide COSEWIC with current knowledge of the biology, abundance, distribution, and life history of the Common Lumpfish in Canadian Atlantic and Arctic waters for use in its evaluation of risk of extinction for this species. In addition, habitat and residence requirements were assessed through analyses of the relationship between research survey catches and water depth/bottom temperature. This document also reviews available information on threats and limiting factors which may impact this species, as well as current management measures.

Examen pré-COSEPAC concernant la lompe (*Cyclopterus lumpus* Linnaeus 1758) dans les eaux canadiennes de l'Atlantique et de l'Arctique

RÉSUMÉ

Aux termes de la Loi sur les espèces en péril (LEP) fédérale, la lompe (*Cyclopterus lumpus*, Linnaeus 1758) doit faire l'objet d'une évaluation par le Comité sur la situation des espèces en péril au Canada (COSEPAC) en novembre 2017. Le principal objectif du présent document est de fournir au COSEPAC les connaissances actuelles sur la biologie, l'abondance, l'aire de répartition et le cycle biologique de la lompe dans les eaux canadiennes de l'Atlantique et de l'Arctique afin qu'il les utilise pour son évaluation du risque d'extinction de cette espèce. En outre, on a évalué les besoins en matière d'habitat et de résidence au moyen d'analyses de la relation entre les prises des relevés de recherche et la profondeur de l'eau/température au fond. Ce document examine aussi les renseignements disponibles sur les menaces et les facteurs limitatifs qui peuvent avoir une incidence sur cette espèce, ainsi que les mesures de gestion actuelles.

INTRODUCTION

Application of the federal *Species at Risk Act* (SARA), proclaimed in June 2003, begins with an assessment of a species' risk of extinction by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). COSEWIC is a non-governmental scientific advisory body that was established under Section 14(1) of SARA to perform species assessments, which provide the scientific foundation for listing species under the Act. A species assessment thus initiates a regulatory process in which the competent Minister must decide whether to accept the COSEWIC designation, and list a species in Schedule 1 of SARA. If listed, that species is then legally protected under the Act. If the species is already listed in Schedule 1, the Minister may then decide to keep the species on the list, reclassify it as per the COSEWIC assessment, or remove it from the list (i.e., Section 27 of SARA).

Fisheries and Oceans Canada (DFO), as a generator and archivist of data on marine species, must provide COSEWIC with the best information available to ensure that an accurate assessment of the status of a species can be undertaken. In support of an assessment of this species by COSEWIC, scheduled for November 2017, this paper summarizes existing information on Common Lumpfish (*Cyclopterus lumpus*) in Canadian Atlantic and Arctic waters. It also presents data to evaluate the status of, and threats to, this species inside and outside of Canadian waters, and identifies strengths and limitations of this information.

OVERVIEW OF BIOLOGY AND LIFE HISTORY

DISTRIBUTION

The Common Lumpfish (Figs. 1A and 1B) is widely distributed in temperate waters on both sides of the North Atlantic Ocean, as well as in the Arctic Ocean (Fig. 2). In the Western Atlantic, its distribution ranges from southwestern Greenland, off of Baffin Island, along the coasts of Newfoundland and Labrador (NL), on the Flemish Cap, in the Gulf of St. Lawrence, off of New Brunswick and Nova Scotia, and as far south as Chesapeake Bay (Fig. 2; Fig. 3). This species is also found in the Hudson and James Bays, and in Foxe Basin. In the Eastern Atlantic, Common Lumpfish occurs off of the Svalbard Islands, in the coastal waters of Iceland and southeastern Greenland, along the coasts of Norway, Denmark, Netherlands, Belgium, United Kingdom, France, and Spain, and as far south as the northern coast of Portugal. Common Lumpfish are also found in the Baltic, Barents, and White Seas.

Common Lumpfish occur from shallow coastal waters (<20 m) to depths of over 300 m (Collins 1978; Able and Irion 1985; Collette and Klein-MacPhee 2002). They tolerate reduced salinity, and have been observed in the St. Lawrence Estuary (Able and Irion 1985). Adults have been reported in the tidal waters of the Miramichi River, New Brunswick (McKenzie 1959). O'Connell et al. (1984) caught a single Common Lumpfish in surface gillnets set close to the mouth of the Crossing Place River in Holyrood Pond on the south coast of Newfoundland, where salinity was 13-27 ppt. There are also Common Lumpfish populations permanently occupying low salinity waters in Hudson Bay and the Baltic Sea (Davenport 1985).

MORPHOLOGY

Detailed descriptions of the Common Lumpfish can be found in Davenport (1985), Goulet et al. (1986), Stevenson and Baird (1988), and Scott and Scott (1988). Common Lumpfish are generally identified by their pentagonal body shape (in cross-section), and large dorsal hump that conceals their first dorsal fin in a frontal view. Covered in a scaleless leathery skin with hard tubercles, their paired pelvic fins are modified to form a ventral sucker or adhesive disc, which is present at hatching. This disc enables these fish to adhere to boulders and other bottom features (even during heavy wave action at intertidal nesting sites), as well as to floating objects, such as marine buoys, docks, and macroalgae (Davenport 1985; Brown 1986; Moring 1989; Moring and Moring 1991; Brown et al. 1992). Common Lumpfish body colour often matches the surroundings; especially in the young. On adults, the main body colour can be slate blue, bluish-grey, olive, brownish to yellow green, or chocolate to kelp brown, while the belly is yellowish to whitish of the same hue (Bigelow and Schroeder 1953).

Common Lumpfish are sexually dimorphic: adult males are smaller in body size than females. Males and females also swim differently: the male tends to employ a powerful tail stroke, while the female relies mainly on her pectoral fins (Davenport and Kjørsvik 1986). During spring spawning in Newfoundland waters, the male's courtship colouration consists of a dark blue body, orange to red fins (dorsal, caudal, anal, and pectoral) and ventral surface, plus a metallic silver patch behind each pectoral fin (Fig. 1A), while adult females do not undergo colour changes (Fig. 1B; Davenport 1985; Goulet et al. 1986).

BIOLOGY AND ECOLOGY

In Norwegian waters, Common Lumpfish males appear to first spawn at ages 2-3, while females do so at ages 3-4 (Albert et al. 2002). Off the coast of Greenland, males and females reach maturity at ages 2-3 (Hedeholm et al. 2014). Females attain sexual maturity at approximately 40 cm in length (i.e., 5-6 years of age) in Iceland (Thorsteinsson 1981), and at 35 cm (age 5) in Newfoundland waters (Grant 2001).

The average number of eggs produced by each adult female per spawning season is 100,000, and depends on body size: the largest females may produce anywhere from 350,000 to 400,000 eggs (Davenport 1985; Muus and Nielsen 1999). In Newfoundland waters, Goulet et al. (1986) found egg masses containing 10,000-200,000 eggs. A fecundity study on Common Lumpfish collected from Divs. 4RS and Subdiv. 3Pn in 2004-05 indicated an average fecundity of 100,000-130,000 eggs for females 30-48 cm in length, with respective somatic weights of 1,200-3,600 g (DFO 2006). In addition, the relationship between egg number and ovary weight was linear (Fig. 4), with an average of approximately 150 eggs per gram. Average size of vitelline oocytes was 1.63 mm, with a range of 0.79-2.23 mm. In addition, no relation was observed between oocyte size and female body size, and oocyte maturation was found to be synchronous. Furthermore, female gonad weight accounted for 28% on average of total body weight (François Grégoire, unpublished data).

Davenport (1985) indicated that Common Lumpfish are semi-pelagic, spending much of their adult lives in the pelagic zone. This was confirmed by catches of these fish in pelagic research surveys of the Barents Sea (Wienerroither et al. 2011, 2013; Eriksen et al. 2014) and the Labrador Sea (Sheehan et al. 2012), and in a salmon survey in the Bay of Fundy and Gulf of Maine (Lacroix and Knox 2005). According to Fahay (2007), they are primarily pelagic, but become demersal during reproduction. Collins (1976) suggested that an inshore spawning migration of Common Lumpfish occurs annually in Newfoundland waters during spring, with spawning usually taking place in May-June in shallow waters. Although Common Lumpfish spawn in the lower intertidal zone in European waters (Zhitenev 1970), they appear to spawn only in subtidal waters in North America (Bigelow and Schroeder 1953). After spawning in intertidal and/or subtidal areas, they move to deeper waters offshore in late summer and early fall.

Common Lumpfish males migrate to inshore spawning areas first and establish territories, building nests at locations of high structural complexity (Davenport 1985; Goulet 1985; Goulet et al. 1986). During Goulet's research on Common Lumpfish reproductive behaviour in Conception Bay (Newfoundland, Canada), individual nesting sites were repeatedly occupied by males over several years; however, whether males returned to the same sites that they occupied in the previous summer remains unknown, because individuals were not tagged in this study (C. Miri, DFO, pers. comm.). Subsequent arrival of females is asynchronous, such that males are able to court multiple mates (Goulet et al. 1986; Goulet and Green 1988). Common Lumpfish are batch spawners, and fertilization is external (Davenport 1985). When a female deposits a mass of unfertilized eggs in a nest, the territorial male immediately releases milt over the eggs to fertilize them (Collette and Klein-MacPhee 2002). Females will spawn with more than one male: depositing their eggs in several batches at intervals of 8-14 days (Shears 1980; Davenport 1985). Eggs are typically deposited in crevices or between boulders on rocky bottoms, often associated with macroalgae, and adhere to each other and the substrate (Cox and Anderson 1922; Mochek 1973; Shears 1980; Davenport 1985; Goulet 1985; Goulet et al. 1986; Fahay 2007).

After external fertilization and departure of the female, each successful male provides parental care: at first, repeatedly pushing his snout into the egg mass to compact and secure it to the hard substrate; guarding the nest against predators; aerating the egg mass by periodically "fanning" his pectoral fins while adhered to a boulder or hard substrate nearby; and removing any debris that may stick to the eggs due to wave action or water currents (Shears 1980; Davenport 1985; Goulet et al. 1986).

After "batch" hatching from male-guarded nests, larvae are found in tidal pools over repeated tidal cycles, and juveniles live in the top 1 m of water during their first year, often attached to floating macroalgae (Bleakney and McAllister 1973; Davenport 1985; Moring 1989; Able and Fahay 1998). In Newfoundland waters, newly-hatched Common Lumpfish are 5-6 mm in length (Collins 1976; Brown et al. 1992), and immediately use their ventral disc to attach to macroalgae, eelgrass, and other hard substrates (Davenport 1985; Brown 1986; Moring 1989; Moring and Moring 1991). Eelgrass beds appear to be particularly important for early developmental stages and, upon reaching 20-25 mm in length, Common Lumpfish associate more with *Laminaria* spp. and *Ascophyllum nodosum* (Moring 1989; Moring and Moring 1991).

In general, Common Lumpfish feed on a wide variety of pelagic and benthic prey, including fish eggs and larvae, ctenophores ("sea gooseberries"), amphipods, copepods, euphausiids, mysids, small fish, polychaetes, and molluscs (Daborn and Gregory 1983; Davenport 1985; Moring 1989). Young-of-the-year (YOY) living in near-surface waters consume zooplankton, primarily copepods and pelagic amphipods (Daborn and Gregory 1983). In shallow tidal pools along the coast of Maine (United States), amphipods and mysids are the principle prey of YOY, although copepods, isopods, cumaceans, and polychaetes are also important (Moring 1989). In the Northeast Atlantic, juvenile Common Lumpfish undergo ontogenetic dietary shifts with increasing body size: smaller individuals consume crustacean larvae and halacarid mites, while larger individuals prefer isopods, amphipods, harpacticoids, and smaller conspecifics (Ingólfsson and Kristjánsson 2002; Vandendriessche et al. 2007). The diet of juveniles is typically less diverse than that of adults, probably due to younger fish having smaller mouths and being less adept at capturing moving prey (Moring 1989).

Common Lumpfish have been reported in predator diet studies as eggs and fish. Few fish have been recorded to prey on Common Lumpfish. Analyses of wolffishes (*Anarhichas* spp.) and Greenland Halibut (*Reinhardtius hippoglossoides*) in the northwest Atlantic had only traces of Common Lumpfish identified among the prey items which were identified (Chumakov and Podrazhanskya 1986; Simpson et al. 2013). For the northern Gulf of St. Lawrence, a groundfish stomach database consisting of thousands of records for Atlantic Cod (*Gadus morhua*), Greenland Halibut, and Atlantic Halibut (*Hippoglossus hippoglossus*) from 1994-2014 contained only five specimens (i.e., three cod and two halibut) with small amounts of Common Lumpfish identified in their stomach contents (D. Chabot, DFO, pers. comm.).

Greenland Sharks (*Somniosus microcephalus*), Sperm Whales (*Physeter macrocephalus*), and seals prey upon adult Common Lumpfish (Roe 1969; Thorsteinsson 1983). Common Lumpfish egg masses are consumed by Ocean Pouts (*Macrozoarces americanus*), Cunners (*Tautogolabrus adspersus*), Green Sea Urchins (*Stronglyocentrus droebachiensis*), and periwinkles (*Littorina* spp.) (Goulet et al. 1986). Common Lumpfish have also been found occasionally in Spiny Dogfish (*Squalus acanthias*) stomachs.

In the northern Gulf of St. Lawrence, Grey Seals (*Halichoerus grypus*) are known to prey on adult Common Lumpfish (Benoît and Bowen 1990*a*). An opportunistic forager, Grey Seals feed on prey species when abundant or aggregated, such as Common Lumpfish during its spring inshore spawning, or as sex-segregated groups offshore in summer. Anticosti Island seals sampled from May to July of 1988 contained large quantities of Common Lumpfish (i.e., 41% of mass average in prey contents), while only traces were identified in August to September of 1992 (Hammill et al. 2007). An earlier study of Anticosti Grey Seal indicated that Common Lumpfish was a major prey item during summer for 3 out of 4 years, with fish lengths ranging between 15 and 29 cm (25 cm mean; Benoît and Bowen 1990*b*).

Common Lumpfish are hosts to a few species of parasitic copepods. In Newfoundland waters, they are intermediate hosts of *Lernaeocera branchialis* ("cod worm", Templeman et al. 1976). Common Lumpfish are also a preferred host of the ectoparasitic copepod *Caligus elongates*, also known as "sea lice" (Øines et al. 2006; Heuch et al. 2007; Øines and Heuch 2007). The protozoans *Cryptobia dahli* and *Trichodina domerguei* are known to infest the stomach and urinary bladder, respectively (Margolis and Arthur 1979).

MOVEMENTS

Tagging studies of adult Common Lumpfish in Newfoundland waters reported recoveries of adult females within 16 km of their tagging site, usually one year after their release, suggesting that adults return to the same spawning grounds each year (Blackwood 1982, 1983). Research conducted off of Denmark (Bagge 1967) and Iceland (Schopka 1974) previously demonstrated that adult Common Lumpfish elicit a strong homing behavior, returning annually to the same spawning grounds. Lee and Christian (2002) reported adults returning to the same spawning grounds each year, with some tagged individuals travelling up to 49 km per day.

In Divs. 4RS and Subdiv. 3Pn, Fréchet et al. (2006, 2011) conducted a Common Lumpfish tagging program in 2004-08 with 3,288 adult females tagged. As of 2015, only 157 individuals have been recaptured, with 72% of recaptures within 25 km of their tagging sites. The longest migration recorded in this study was 300 km over a three-month period, with movements occurring along the south coast of Newfoundland (Fig. 6). Kennedy et al. (2014) also reported that adults tagged in coastal areas travelled up to 587 km.

GENERATION TIME

Generation time for Common Lumpfish was estimated as 5 years, based on the Fishbase.org life history tool (Froese and Pauly 2015). However, when generation time is calculated as $G=t_{mat} + 1/M$ (where t_{mat} is age at maturity [5 years], and M is natural mortality [0.2]), the resulting value is 10 years. The choice of 0.2 as M is arbitrary and, in this case, does not accurately reflect the biology of this animal. Examination of various estimates from empirical relationships, using growth/size and maturity data from several studies of Common Lumpfish, yielded an M of 0.3, and a G of 7 years (Atkinson and Kulka, pers. comm.).

SPECIALISED NICHE OR HABITAT REQUIREMENTS

As indicated previously, eelgrass (*Zostera marina*) and macroalgae (*Laminaria* spp. and *Ascophyllum nodosum*) are particularly important for early life stages of Common Lumpfish.

Along the coasts of the Gulf of St. Lawrence, inshore eelgrass beds on sandy bottoms were monitored for juvenile fishes: including Common Lumpfish, Smelt (*Osmerus mordax*), and Atlantic Cod (e.g., Gotceites et al. 1997). Several sites were also surveyed in the St. Lawrence Estuary and Gulf (Grant and Provencher 2007; Nellis et al. 2012; Dutil et al. 2013). Along the Gulf north shore, large Common Lumpfish (>20 cm TL) were captured in spring, while 15-60 mm post-larvae were collected in beach seines throughout summer.

Adults require suitable nest sites for spawning each spring. As described previously, males migrate inshore first, and establish territories in areas of high structural complexity. Females then move inshore and deposit adhesive eggs on suitable substrates, usually in crevices or between boulders on rocky bottoms with macroalgal cover.

CONCEPT OF RESIDENCE FOR COMMON LUMPFISH

The *Species at Risk Act* defines "residence" as:

"a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating" (s.2(1)).

The 2015 policy document entitled, "DFO's Guidelines for the Identification of Residence and Preparation of a Residence Statement for an Aquatic Species at Risk" (unpublished report) states that the following four conditions should be used to determine whether the concept of residence applies to an aquatic species:

1. There is a discrete dwelling-place that has structural form and function similar to a den or nest or other similar area;
2. An individual of the species has made an investment in the creating and/or modifying the dwelling-place;
3. The dwelling-place has the functional capacity to support the successful performance of an essential life-cycle process such as spawning, breeding, nursing and rearing; and
4. The dwelling-place is occupied by one or more individuals at one or more parts of their life cycle.

Based on these criteria, Common Lumpfish mating/nesting sites would constitute residences, since adult males construct dens for the eggs; they also modify and protect the area once the eggs are deposited. These dens support reproduction (an essential life-cycle process) and are occupied by both adults and larvae.

As mentioned previously, tagging studies (Schopka 1974; Fréchet et al. 2011) strongly suggest homing to inshore spawning grounds in spring, so these sites should be considered as breeding residences. Directed fisheries targeting adults, as well as removals due to bycatch in other fisheries, that occur near or at these breeding sites in spring/summer could negatively impact reproduction and recruitment.

SURVEY DATA

Standard bottom trawl surveys are not ideal to evaluate population biomass or trends in abundance for Common Lumpfish due to the species' semi-pelagic nature, and seasonal inshore spawning migrations that result in a portion of the population being unavailable to such surveys. However, given the long time-series (i.e., >30 years) of several DFO research surveys, it is likely that the associated data reflect the general species distribution. In bottom trawl and pelagic surveys conducted simultaneously in the Barents Sea, catches of Common Lumpfish were much greater in the pelagic survey, although the bottom trawl survey was broadly indicative of their distribution (Wienerroither et al. 2011, 2013; Eriksen et al. 2014).

NEWFOUNDLAND AND LABRADOR REGION

Data were obtained during DFO-NL multi-species bottom trawl surveys conducted over the continental shelves of Newfoundland and Labrador (Divs. 2GHJ3KLNOP) in spring (1971-2014; Table 1) and fall (1977-2014; Table 2), including areas beyond the Canadian Exclusive Economic Zone (EEZ; Fig. 3). These research surveys employed a stratified random design based on depth intervals and location (latitude, longitude), and were designed to provide information on abundance, distribution, and area occupied by numerous demersal and benthic fish, as well as several invertebrate species. Details of these surveys, including changes in gear type and spatial coverage over time, are discussed in Doubleday (1981), Bishop (1994), McCallum and Walsh (1996), Walsh and McCallum (1996), Brodie and Stansbury (2007), Healey and Brodie (2009), and Simpson and Miri (2013). It should be noted that, due to different trawls being deployed during the spring (Yankee 41.5 in 1971-83; Engel 145 in 1984-95; and Campelen 1800 in 1996-2014) and fall (Engel 145 in 1977-94; Campelen 1800 in 1995-2014) surveys, combined with a lack of conversion factors to account for differences in Common Lumpfish catchability due to these gear changes, the resultant survey time series are not directly comparable. In addition, fall surveys reach deeper maximum depths (~1,400 m) than those in spring (~750 m). Therefore, fall survey data are not directly comparable to spring survey data. It should be noted that the spring survey was incomplete in 2006 due to partial sampling of Divs. 3NO and almost no coverage of Subdiv. 3Ps. In addition, the fall survey was incomplete in 2014 due to partial coverage of Div. 3L and no sampling of Divs. 3NO. Subdiv. 3Pn was not surveyed in spring 2008 and 2014.

The majority of Common Lumpfish in the NL Region occur in Div. 3P and Div. 4R. The spring survey, which covers Div. 3P, should serve as the primary source of abundance and biomass data. However, this survey is conducted during a period when Common Lumpfish tend to be concentrated inshore, at depths that are not sampled. This inshore movement appears to be temperature dependent, so there may be considerable interannual variability in Common Lumpfish availability during the spring survey sampling.

MARITIMES REGION

The DFO-MAR summer research survey has been conducted annually on the Scotian Shelf (Divs. 4VWX5Yb) since 1970, using a stratified random design based on depth and geographic area. There were forty-two survey strata grouped into three categories based on depth: <92 m, 92-181 m, and >181 m. In 1995, coverage was expanded into three deepwater strata (i.e., 365-732 m) on the shelf edge. Various vessels and bottom trawl types (primarily Western IIA) were used over the span of this survey (see Claytor et al. 2014 for details).

The March 4VsW research survey was conducted on the eastern half of the Scotian Shelf in 1986-2010 (Claytor et al. 2014). This survey did not include all of Divs. 4VW, used a stratification scheme differing from that of the summer survey, and attempted to optimize abundance estimates for Atlantic Cod in Divs. 4VsW. No surveys were conducted in 1998 or 2004, and the 2009 survey was incomplete. The CCGS *Alfred Needler* was used in all years with a Western IIA trawl (except for 2007 and 2008). The same gear was deployed using the CCGS *Wilfred Templeman* in 2007 and the CCGS *Teleost* in 2008. In 1993, deepwater strata (i.e., 365-549 m) in the Laurentian Channel were added to this survey. Coverage of eastern strata was restricted in some years due to ice coverage.

The Georges Bank winter research survey (Subdiv. 5Z) commenced in 1986, using a Western IIA trawl and a stratified random design (Fig. 7). This survey is concentrated on the Canadian side of the bank (Subdiv. 5Zc), with additional sets on the American side of Georges Bank, as well as some sampling sites north of the bank.

GULF REGION

The DFO-Gulf bottom trawl survey of the southern Gulf of St. Lawrence (sGSL) has been conducted annually in September since 1971, and used a stratified random design (see Hurlbut and Clay 1990, and Chadwick et al. 2007 for details). The standard research tow in all years was 30 minutes in duration, at a speed of 3.5 knots, and all catches were adjusted to 1.75 nautical miles.

The sGSL survey has been conducted by different research vessels and trawls (see Benoît 2014 for details): *E.E. Prince* (1971-85) using a Yankee 36 trawl; and fishing a Western IIA trawl was the *Lady Hammond* (1985-91), CCGS *Alfred Needler* (1992-2002, 2004-05), CCGS *Wilfred Templeman* (2003), and CCGS *Teleost* (2004-present). Prior to the gear change and all but one of the vessel changes (CCGS *Wilfred Templeman*), paired tows involving both vessels and trawls were conducted at common sites to estimate their relative catchabilities (Benoît and Swain 2003; Benoît 2006). In every case, Common Lumpfish were seldom caught in paired tows, thereby precluding any estimation of a conversion factor. Consequently, each vessel/gear combination is assumed to capture this species with the same efficiency.

A common group of strata (i.e., 415-439), covering most of the survey area (70,061 km^2), were sampled annually since 1971 (Fig. 8). The number of valid fishing sets completed annually in these strata varied from approximately 70 (in the early 1980s) to >160 (during the 1990s and 2000s). Three nearshore strata were added to this survey in 1984 (401-403), but these data were not included here to maintain a standardized series for 1971-2014, and because Common Lumpfish have rarely been captured in these strata. Aside from these nearshore additions, both survey timing and area remained constant since 1971. In a few instances, some strata were not sampled in particular years: strata 424 and 428 were not surveyed in 1978, and stratum 421 was not surveyed in 1983 and 1988. In order to maintain a consistent survey area, for the years when these strata were not surveyed, their catch weights were added to those of neighbouring strata (i.e., at the same depths) for calculations of stratified mean catch rates and distribution indices. In 2003, deeper water strata 438 and 439 were not surveyed. Furthermore, Common Lumpfish were not caught in these strata over three years preceding or following 2003, so it was assumed that they would not be found in these strata during 2003.

The sGSL survey was restricted to daylight (0700-1900 hrs) in 1971-84, but has since been conducted 24 hours per day. Common Lumpfish were found to be significantly more catchable during daylight by the CCGS *Alfred Needler* (2.1 times), but not by the *Lady Hammond* (Benoît and Swain 2003). Using the same methods as the previous study, no statistically significant diel effect was detected for CCGS *Teleost* tows in 2004-14 (p=0.842; H. Benoît unpublished). Therefore, nighttime catches by CCGS *Alfred Needler* were adjusted to daytime equivalents for this analysis.

QUEBEC REGION

DFO Surveys

Data from two DFO-QC bottom trawl groundfish surveys were analysed (Table 3): a winter survey conducted in January 1978-94, and a summer survey in August 1990-2014. Both surveys were designed to provide abundance indices for commercial groundfish species in the northern Gulf of St. Lawrence (nGSL) and Estuary, using a stratified random design based on depth and geographic area (Fig. 9A; see Bourdages et al. 2015 for details). In general, the surveyed area includes the Laurentian Channel and north: from the lower Estuary in the west to the Strait of Belle Isle and Cabot Strait in the east (i.e., Divs. 4RS, depth strata >183 m in the northern part of Div. 4T; Fig. 9A, Fig. 9B). Subdiv. 3Pn was covered in the winter survey and from 1993 to 2004 in the summer survey. Data from these two series are not comparable due in part to differences in seasonality, trawl, and vessel.

The winter survey used an Engel 145 trawl on the *Gadus Atlantica* (no survey in 1982). The area surveyed was highly variable over the years, due in part to ice cover. The Lower Estuary in Div. 4T (strata 409–414) was not surveyed. Coverage of Subdiv. 3Pn and Div. 4R was relatively constant, while coverage of Divs. 4ST was more variable. Therefore, abundance indices were only calculated for Subdiv. 3Pn and Div. 4R.

In 1990-2003 and in 2005, the summer survey used a URI 81'/114' (University of Rhode Island) shrimp trawl on the CCGS *Alfred Needler*. Since 2004, this survey used a Campelen shrimp trawl on the CCGS *Teleost*. Comparative fishing experiments were done during the nGSL summer survey in 2004 and 2005 to estimate the catchability difference between the vessel/trawl combinations (Bourdages et al. 2007). The conclusion for Common Lumpfish is that vessel/trawl combinations have no effect on its catchability; no correction was required to combine data from the two summer survey series.

Sentinel Program – July Mobile Survey

Data from a Sentinel Program conducted annually, since 1995, as a July groundfish mobile gear survey were also examined (Table 3). This survey used a depth-stratified random design and sampling methodology similar to DFO-QC nGSL summer surveys, and consisted of 300 sites randomly selected and sampled by commercial trawlers from Newfoundland and Quebec. However, Estuary strata (i.e., 411, 412, 413; Fig. 9) were not surveyed, while Subdiv. 3Pn was.

CENTRAL AND ARCTIC REGION

DFO-Central and Arctic (C&A) deep-water bottom trawl surveys were conducted in Div. 0A (Baffin Bay) in fall 1999, 2001 (southern Div. 0A), and in every second year over 2004-12 (southern 0A; northern Div. 0A and inshore areas added in particular years), using a stratified random design (based on depth) and the research vessel *Pâmiut*. Div. 0B was also surveyed in 2000, 2001, 2011, and 2013 by the *Pâmiut*. A new annual survey of southern Div. 0A (i.e., to 72°N) and Div. 0B (Fig. 10) by the *Pâmiut* started in 2014. From 2006-13, DFO-C&A surveys used two gear types: an in Div. 0A and 0B targeting Greenland Halibut at depths of 400-1,500 m; and a Cosmos® 2000 shrimp trawl in Div. 0A and the Western Assessment Zone (WAZ) targeting Northern Shrimp (*Pandalus borealis*) and Striped Shrimp (*P. montagui*; 100-800 m). The survey that commenced in 2014 uses only the Alfredo III otter trawl and targets Greenland Halibut. Furthermore, the Northern Shrimp Research Foundation (NSRF) conducted annual surveys using a Campelen 1800 shrimp trawl in Shrimp Fishing Areas (SFAs) 2EX and RISA (Fig. 10), and added the WAZ to its surveyed areas in 2014. The changes in survey design and coverage instituted in 2014 provide greater consistency in area and periodicity than the past surveys, while ensuring that annual surveys targeting Greenland Halibut and Northern and Striped Shrimp continue in the Eastern Canadian Arctic. In addition to assessing abundance, distribution, and area occupied by target species, these surveys provided data on many demersal and benthic fish and invertebrate species.

OTHER SURVEYS

Canadian Pelagic Survey

DFO-NL conducted a pelagic ecosystem survey of the Northwest Atlantic in August 2008 and 2009, using CCGS *Wilfred Templeman* equipped with a post-smolt trawl and pelagic doors to target Atlantic Salmon (*Salmo salar* L.; Sheehan et al. 2012),

US Survey

Spring and fall stratified-random bottom trawl surveys were conducted since 1968 and 1963 (respectively) by the US Northeast Fisheries Science Center (NFSC), sampling 9-366 m depths from Cape Hatteras (North Carolina) to beyond Canada's EEZ.

SPATIAL DISTRIBUTION AND HABITAT ASSOCIATION

Spatial distribution of Common Lumpfish was investigated using point plots of the geographic distribution of standardized catch rate (number of fish per tow) for each regional survey series. In addition, density surface maps of the geographic distributions of standardized catch rate (number of fish per tow) for Common Lumpfish were created with ArcGIS 10.1 for each regional survey-series (NL, MAR, Gulf, QC); except for DFO-C&A, which generated similar maps with Subarea 0 survey data. Prediction density surfaces were estimated using Kernel interpolation. A radially symmetric Epanechnikov kernel with first order polynomials was used to generate Common Lumpfish density surfaces for each map.

NEWFOUNDLAND AND LABRADOR REGION

Point maps of DFO-NL standardized catch rates from spring (Figs. 11-14) and fall (Figs. 15-18) research surveys indicated that Common Lumpfish distribution varied inter-annually. This variability may represent seasonal changes related to inshore spawning migrations in spring. In Subdiv. 3Ps and 3Pn, Common Lumpfish were distributed from inshore bays to the shelf edge in some years (e.g., spring 1997, 2001), and were also caught in very few locations in other years (spring 1998-2000). Similarly, Common Lumpfish were found across the Newfoundland and Labrador Shelf from inshore to the shelf edge during fall surveys in some years, whereas their catches were more restricted to inshore areas in other years. In addition, the range and size of Common Lumpfish catches has declined in spring and fall surveys: surface density plots indicated that most Common Lumpfish were found in Subdiv. 3Ps in spring through the 1980s and early 1990s (Fig. 19) and, to a lesser extent, in Divs. 2J3K in fall since the mid-1990s, and Div. 3L since 2000 (Fig. 20).

Furthermore, the association of Common Lumpfish density with depth and bottom temperature in Divs. 2J3KLNOP was studied using cumulative distribution functions (Perry and Smith 1994; Smith 1996). This method involved the construction of a design-weighted cumulative distribution function (cdf) of an observed habitat variable (i.e., temperature or depth) for a given year, as well as a catch-weighted cdf (based on proportions of the stratified mean associated with each point of the design-weighted cdf). The two curves were then compared to evaluate any difference between them.

Cumulative frequency distributions (CFDs) of depths and bottom temperatures encountered in spring surveys of Div. 3P, and depths and temperatures associated with Common Lumpfish catches in this division, are presented for 1996-2014 (Fig. 21). CFDs of depths and bottom temperatures found in Divs. 2J3K, and depths and temperatures associated with Common Lumpfish catches in these divisions, are presented for fall survey data from 1995-2013 (Fig. 22). CFDs of depths (Fig. 23) and bottom temperatures (Fig. 24) observed in Divs. 3LNO, and temperatures associated with Common Lumpfish catches in these divisions, are presented for survey data from spring 1996-2014 and fall 1995-2013. Overall, results suggested that Common Lumpfish prefer waters ≤4°C, which was consistent with Kulka and Templeman (2013). In Newfoundland and Labrador waters, Common Lumpfish were typically found in <400 m depths, and no seasonal trends in temperature or depth associations were apparent (the latter based on Divs. 3LNO survey data).

MARITIMES REGION

Common Lumpfish were caught infrequently in DFO-MAR research surveys. In the summer research survey, they were found predominantly in Div. 4X: often near the mouth of the Bay of Fundy, and/or border of Div. 5Y (Figs. 25-28). In the March 4VsW research survey, Common Lumpfish catches mainly occurred in Subdiv. 4Vs (Figs. 29-31). They were rarely captured in the Georges Bank winter research survey (Subdiv. 5Ze; Figs. 32-35). Surface density plots showed that most Common Lumpfish were found during the March 4VsW research surveys on the edge of the Scotian Shelf in Div. 4Vs adjacent to the Laurentian Channel (Fig. 36; Fig. 37), and in much lower densities along the north edges of Georges Bank during the winter research survey (Fig. 38).

GULF REGION

In DFO-Gulf research surveys, Common Lumpfish were found infrequently in Div. 4T (Figs. 39-42), with a great deal of inter-annual variability in catch location and magnitude: largest catches occurred in some years close to the Div. 4S border, or around Prince Edward Island in other years. A surface density plot of Common Lumpfish catches over the last decade was consistent with historical distribution patterns (i.e., from 1995-2004), suggesting that density was low throughout the sGSL. Most catches occurred near the northern boundary of the surveyed areas (i.e., off of Gaspe Peninsula and in the Baie des Chaleurs; Fig. 43).

QUEBEC REGION

Point maps of DFO-QC standardized catch rates from annual nGSL summer surveys (1995-2014) are presented in Figures 44-47, and Common Lumpfish distribution from different mobile surveys in Figures 48-49. The January survey (1978-94) indicated that Common Lumpfish were most abundant in Subdiv. 3Pn and southern Div. 4R in 91-274 m depths, with highest densities in Subdiv. 3Pn (especially along southwestern Newfoundland; Figs. 48, 49) and continuity between Subdiv. 3Pn and Div. 4R.

Catches of Common Lumpfish in the August survey (1990-2014) were small, and occurred mainly northwest and northeast of Anticosti Island, at the head of Esquiman Channel, and in the approaches of the Strait of Belle Isle (Fig. 50). In 2014, most catches occurred in Bay of Sept-Iles and north of Anticosti Island. In 2011-2014, Common Lumpfish were also found close to the coast on the north side of the lower Estuary, partly due to the addition of shallower survey strata (i.e., 37-183 m) since 2008.

In 1990-94, winter survey catches of Common Lumpfish were much larger and at greater depths (>200 m) as compared to summer surveys (Fig. 51), possibly signifying aggregations near the bottom and increased susceptibility to the survey trawl. This apparent difference in catchability was also found between winter and summer bottom trawl surveys in the Barents Sea (Wienerroither et al. 2013). It must be noted that selectivity varied between both DFO-QC surveys, due to differences in timing (January *versus* August) and in the trawl-vessel combination deployed.

The Sentinel July mobile gear survey indicated the same Common Lumpfish distribution as the DFO-QC August survey: the Bay of Sept-Iles, northwest and northeast of Anticosti Island, at the head of Esquiman Channel, and the approaches of the Strait of Belle Isle (Fig. 52). This survey also found Common Lumpfish in Subdiv. 3Pn, and continuity with Div. 4R.

Maps of Common Lumpfish catches are presented for the nGSL summer surveys for years where length data were collected (Fig. 53). Three length classes were defined: the 30-170 mm class, which is representative of the first mode of a bimodal distribution observed in the summer survey; the 170-340 mm immature intermediate class; the ≥340 mm class, indicative of mature population. The map indicates that small (<170 mm) Common Lumpfish are present throughout the surveyed area, while the mature individuals (≥340 mm) are absent from the Laurentian Channel up to the Estuary (where only one mature fish was caught). These small individuals were caught in areas where the water depth reaches more than 300 m. Mature Common Lumpfish catches are seen on the 200 m isobath of the northern flank of the Esquiman Channel, up to the Strait of Belle Isle, north of Anticosti Island, and in the Bay of Sept-Iles.

A surface density plot of summer survey catches in the last decade indicate that Common Lumpfish density was highest along Quebec's northern shore and Anticosti Island; density of this species was patchy and much lower along the west coast of Newfoundland (Fig. 54).

Summer data regarding nGSL physicochemical variables and depth indicate that survey sites were influenced by different environmental conditions (Fig. 55). Most sites located in 50-200 m depths had conditions corresponding to the ocean's cold intermediate layer: water temperature <2°C; salinity of ~31 to ~34% which increased with depth; and a concentration of dissolved oxygen which increased to 150-350 µM towards the surface. Survey sites deeper than 300 m were influenced by the ocean's deep water mass: stable temperature (~5°C) and salinity (~34.5%), and oxygen concentration that increased with depth. Common Lumpfish habitat preferences in the nGSL were investigated by plotting CFDs of bottom temperatures surveyed and temperatures associated with Common Lumpfish catches, as well as for dissolved oxygen, salinity, and depth (Fig. 56). Overall, Common Lumpfish were caught in all environmental conditions surveyed, and were more abundant in 2-5°C waters and 125-300 m depths.

CENTRAL AND ARCTIC REGION

Catch data from DFO-C&A SA 0 bottom trawl surveys were plotted (number of fish per tow) to investigate Common Lumpfish distribution by year (Fig. 57). Kernel density plots were also created using ArcGis 10.1 (Fig. 58). Catches were very low (0-7 fish per tow), and occurred in 130-1,243 m depths.

OTHER SURVEYS

Canadian Pelagic Survey

Common Lumpfish were caught in 28 sets (of 46 in total) and 12 (of 21 total) sets in 2008 and 2009, respectively (Sheehan et al. 2012), and were distributed across the NL Shelf and over deep areas of the continental shelf (Fig. 59).

US survey

During the US NFSC spring survey, Common Lumpfish in the Gulf of Maine were more concentrated in coastal waters, as compared to a more widespread distribution during the fall NFSC survey (Fig. 60); thereby reflecting the seasonal spawning migrations of adults.

AREA OF OCCUPANCY

The design-weighted area of occupancy (A_t) for Common Lumpfish was calculated in each year t as follows:

$$(1) \qquad A_t = \sum_{k=1}^{S} \sum_{j=1}^{N_k} \sum_{i=1}^{n_j} \frac{a_k}{N_k n_j} I \quad \text{where } I = \begin{cases} 1 \text{ if } Y_{ijkl} > 0 \\ 0 \text{ otherwise} \end{cases}$$

where Y_{ijkl} is the number of fish in length interval l caught in tow i at site j in stratum k, a_k is the area of the stratum k (km^2), N_k is the number of sites sampled in stratum k, n_j is the number of tows conducted at site j, and S is the number of strata.

NEWFOUNDLAND AND LABRADOR REGION

DFO-NL survey data were used to conduct design-weighted area of occupancy (DWAO) analyses for Div. 3P (spring), Divs. 3LNO (spring, fall), and Divs. 2J3K (fall). Common Lumpfish DWAO has decreased in both spring (Fig. 61, top panel) and fall (Fig. 61, bottom panel) surveys: spring DWAO declined in Div. 3P since the early 2000s, and fall DWAO decreased in Divs. 3LNO (over 2004-05) and Divs. 2J3K (in 2006-09). Given the annual inshore spawning migration of adults, DWAO in Divs. 3LNO remained negligible over the entire spring survey.

MARITIMES REGION

DFO-MAR surveys indicated that summer (Fig. 62) DWAO fluctuated around the long-term mean. The Georges Bank winter and March 4VsW research surveys (Fig. 63) are poor indicators of area of occupancy, especially in area 5Z where there were often no catches of lumpfish. Since Common Lumpfish are infrequently caught in both surveys, DWAO does not reflect the actual density/distribution of this species in the region.

GULF REGION

DFO-Gulf survey data from the sGSL were used to generate DWAO indices for adult and immature Common Lumpfish. Although fluctuating over 1971-2014, the adult DWAO appeared to decline and remain at a low level since 1996, while immature DWAO fluctuated around the long-term mean (Fig. 64).

QUEBEC REGION

DFO-QC nGSL summer survey data were used to calculate Common Lumpfish DWAO for total population. DWAO fluctuated without much trend in 1991-2014 (Fig. 65). Area occupied varied from 3,000 to 27,000 km^2. An apparent increase between 1991-2003 and 2005-14 coincided with a change in survey vessel and trawl gear (Bourdages et al. 2007; Bourdages and Ouellet 2011).

CENTRAL AND ARCTIC REGION

DFO-C&A catches of Common Lumpfish in bottom trawl surveys were insufficient for a meaningful analysis of DWAO over time. Total annual catches, summed over the DFO and NSRF surveys, ranged from 0 to 16 fish. An investigation DWAO trends is further complicated by the alternation of survey area between Divs. 0A and 0B in the RV *Pâmiut* time series. However, changes to the DFO and NSRF surveys, which were implemented in 2014, should facilitate more consistent data collection to enable future analyses of Common Lumpfish catches.

ABUNDANCE AND BIOMASS INDICES

NEWFOUNDLAND AND LABRADOR REGION

DFO-NL survey abundance and biomass indices for were expressed as mean fish number per standard tow and mean weight (in kg) per standard tow, respectively, for spring (Divs. 3LNOP) and fall (Divs. 2J3KLNO). Total abundance values from both spring and fall surveys were also estimated. These indices were estimated by areal expansion of the stratified mean catch per tow (Smith and Somerton 1981).

In 1971-83 (Yankee trawl), catches of Common Lumpfish were sporadic and generally low in Subdiv. 3Ps; although spring abundance and biomass indices peaked in 1973 at approximately 25 fish/tow and 85 kg/tow, respectively (Fig. 66). Both indices then declined to negligible levels, and increased dramatically in 1979, to approximately 25 fish/tow and 85 kg/tow, followed by a precipitous decline. Over 1984-95 (Engel trawl), catches were generally higher: averaging 22 fish/tow and 53 kg/tow. In 1996-2014 (Campelen trawl), abundance and biomass indices were lower: averaging 1 fish/tow and 1.8 kg/tow (excluding 2006). Due to the lack of a conversion factor, it is unknown whether the differences are due to a change in resource status or differences in catchability between the two trawls. In Subdiv. 3Pn, abundance and biomass indices varied considerably over 1986-95 (Engel): peaking in 1991 at approximately 45 fish/tow and 60 kg/tow (respectively), and averaging 10 fish/tow and 18.6 kg/tow. From 1996-2014 (i.e., Campelen series), inconsistent coverage of Subdiv. 3Pn, as well as sporadic catches of Common Lumpfish, resulted in lower abundance and biomass indices, averaging 1 fish/tow and 2.14 kg/tow, respectively. Over 1996-2014, spring abundance and biomass indices for Divs. 3LNO averaged 0.04 fish/tow and 0.09 kg/tow, respectively (Fig. 67). Total abundance of Common Lumpfish from the spring survey is presented in Figure 68.

Fall abundance and biomass indices for Common Lumpfish in Divs. 2J3KLNO (1977-94; Engel trawl) varied considerably over time (Fig. 69), due in part to expansion of survey coverage (e.g., Divs. 3LNO was added in 1990). Abundance and biomass indices remained low (<0.5 fish/tow and 1.0 kg/tow, respectively), then increased substantially over 1986-94 due to increases in Divs. 2J3K. Indices generally remained low until the introduction of the Campelen trawl in fall 1995, whereupon both indices increased but remained below 1.5 fish/tow and 1.5 kg/tow, respectively. In Div. 3L, abundance and biomass indices peaked at approximately 2 fish/tow and 4 kg/tow in 2004. Over 1995-2014, abundance and biomass indices averaged 0.36 fish/tow and 0.66 kg/tow, respectively. Total abundance of Common Lumpfish from the fall surveys is presented in Figure 70.

MARITIMES REGION

DFO-MAR survey abundance and biomass indices were expressed as mean fish number per standard tow and mean weight (in kg) per standard tow, respectively, for winter (Divs. 4VsW, Div. 5z) and summer (Div. 4Vn, Divs. VsW, Div. 4X).

Given that less than 3% of survey tows in 1970-2015 captured Common Lumpfish, analysis of such sporadic catches was not robust. There were 289 catches from summer surveys and 519 from winter surveys. Biomass indices were estimated only for Divisions with the longest survey time-series: highest estimates were found in 4VsW during the March research surveys (Fig. 71), and for Div. 4X in summer (Fig. 72).

GULF REGION

DFO-Gulf survey abundance and biomass indices were expressed as mean fish number per standard tow and mean weight (in kg) per standard tow (respectively) for sGSL (Div. 4T).

Irrespective of trawl used, both indices varied without trend, and were generally low (Fig. 73). The abundance index averaged 0.06 fish/tow over 1971-85 (Yankee trawl), and 0.08 fish/tow in 1986-2014 (Western IIA trawl). The biomass index averaged 0.09 kg/tow in 1971-85, and 0.06 kg/tow over 1986-2014.

QUEBEC REGION

DFO-QC survey abundance and biomass indices were expressed as mean fish number per standard tow and mean weight in kg per standard tow (respectively) for nGSL. It is important to reiterate that Common Lumpfish are semi-pelagic, so their catchability in bottom trawls remains unknown, and is possibly low. Therefore, any abundance estimates should be considered with caution.

The winter survey over 1978-94 was highly variable, due primarily to surface ice preventing fishing. The average area surveyed was 62,550 km^2, and ranged from 31,737 km^2 (1992) to 100,400 km^2 (1980). Survey coverage of Subdiv. 3Pn (all strata) and Div. 4R (only strata consistently covered during the survey) was relatively consistent, while that of Divs. 4ST was more variable. In Subdiv. 3Pn, mean number per tow averaged 3.2 fish, and mean weight per tow averaged 7.8 kg overall (Fig. 74). The abundance index was low and relatively stable in 1978-89, higher over 1990-93 (peak of 17.4 fish/tow in 1990), and decreased below average in 1994. In Div. 4R, the abundance index averaged 3.3 fish/tow, and the biomass index averaged 4.5 kg overall (Fig. 75).

Common Lumpfish were caught infrequently in the summer nGSL survey: annually averaging 30 fish over 20 standard tows. In 2014, 41 individuals were captured over 26 tows. Abundance and biomass indices were generally low and stable (Fig. 76). In 2014, both indices were slightly above the 1990-2013 average: 0.29 fish/tow and 0.16 kg/tow, respectively. Overall, no trends in abundance or biomass were apparent in nGSL surveys.

CENTRAL AND ARCTIC REGION

Abundance was not estimated for Common Lumpfish in SA 0 due to very small annual sample sizes. No trends were found in total number of Common Lumpfish caught (Fig. 77).

SIZE AND MATURITY

Length-weight relationships for Canadian Lumpfish were compared to those from Greenland waters. Length-total weight and length-somatic weight relationships derived from western Greenland data were comparable to those from nGSL (Fig. 78).

Common Lumpfish maturity for Atlantic Canadian waters was based on fish length (≥34 cm for adults; <34 cm for juveniles), using information from Davenport (1985) and Stevenson and Baird (1988). It is worth noting that nesting males measuring less than 34 cm TL have been observed in Conception Bay, NL (J. Green, Memorial University, pers. comm.)

Limited information was available regarding size at maturity for Common Lumpfish in NL waters. DFO-NL research survey catches in 1988-2014 were widely distributed from Div. 2H, off of Labrador, to Div. 3P, off of southern Newfoundland. However, data were insufficient to statistically test for sex-based or latitudinal differences in maturity. In DFO-NL spring surveys of Divs. 3LNOPs over 1984-2014, females ranged in length from 4-58 cm (40 cm mode), while males ranged from 5-50 cm (30 cm mode; Fig. 79). In addition, the Canadian pelagic survey caught 5-46 cm Common Lumpfish, with modal lengths of 13 and 30 cm (Fig. 80); a mostly linear length-weight relationship was associated with Common Lumpfish ≥20 cm TL (Fig. 81).

Common Lumpfish are not sexed in DFO-MAR winter and summer surveys; however based on the assumption that adults were ≥34 cm and juveniles were <34 cm, 58% of those caught were adults and 42% were juveniles, based on the length frequency distribution. Adult sizes ranged from 34-68 cm and averaged 42 cm; juvenile sizes ranged from 3-33 cm and averaged 23 cm (Fig. 82).

In DFO-Gulf sGSL surveys of Div. 4T, abundance (mean number of fish/tow) and biomass (mean weight in kg/tow) indices are presented for immature and mature components of the population (Fig. 83). Both indices tended to be higher for juveniles, due in part to their higher catchability in demersal trawls. Overall, indices for juveniles and adults varied without trend throughout the time-series, irrespective of the type of trawl used.

In the absence of age determination, no information was available from DFO-QC surveys regarding mean size at age and age at maturity of Common Lumpfish in the nGSL. The August survey caught Common Lumpfish ranging from 4-48 cm in length, with a bimodal distribution: one mode of 10-15 cm fish, and another of 20-40 cm (Fig. 84). There were very few Common Lumpfish between 15 and 20 cm, which may represent the growth interval between two successive year-classes. This bimodal distribution of Common Lumpfish sizes was also observed in other surveys, such as the Canadian pelagic survey mentioned previously, and the Barents Sea survey (Wienerroither et al. 2011). The majority of Common Lumpfish caught in the nGSL survey were of non-commercial size (i.e., mean commercial length was 40 cm in Subdiv. 3Pn and Divs. 4RS). Females reached larger sizes than males, and constituted the majority of fish ≥34 cm. The sex ratio for those >19 cm was close to 1. The associated length-weight relationship is also shown in Figure 84. Abundance indices for total, immature, and mature components of the nGSL population are presented in Figure 85. Very few adults (i.e., ≥34 cm) were caught in this survey.

Individual measurements were available for 12 Common Lumpfish caught in 2007-14 during DFO-C&A surveys (Table 4). Fish length ranged from 7-41 cm; weight ranged from 0.014-3.446 kg. Due to the very small sample size, no trends could be observed with respect to Common Lumpfish length or weight over time (Fig. 86).

COMMERCIAL FISHERIES REMOVALS

Commercial fisheries removals of Common Lumpfish in Divs. 3LNOP and Divs. 4RS were examined for 1970-2014, using commercial data in three databases: the NAFO STATLANT-21A landings (1970-2014), as reported by NAFO-member countries; DFO-Zonal Interchange File Format (ZIFF) landings (1985-2014), as reported by Canadian fishers (recorded in their logbooks and on fish plants' purchase slips); and Canadian At-Sea Fisheries Observers' (ASO) catch and discard data (1983-2014), collected on a set-by-set basis in a standardized format on board commercial fishing vessels at sea. Canadian ASOs constitute the only reliable source of data on total catch by species, and discarding at sea. NAFO-reported Common Lumpfish landings are presented in Table 5 and Figure 87. It is important to note that the information contained in the STATLANT-21A database is inconsistent with published data on Common Lumpfish landings from other sources, and should therefore be considered incomplete for the purpose of evaluating removals of this species.

In Atlantic Canadian waters, the Common Lumpfish-directed fishery targets females almost exclusively, which are harvested to collect unfertilized eggs (roe) that are marketed as caviar. The Canadian Common Lumpfish roe fishery developed in the early 1970s in Divs. 3KL, Subdiv. 3Ps, and Div. 4R. In Subdiv. 3Pn, a Common Lumpfish-directed fishery began in 1980, then in 1986 for Div. 4S. This fishery occurs in shallow coastal waters for a few weeks between April and July, and is conducted primarily by small vessels (i.e., those <35 feet in length) using gillnets with 10½-inch mesh. This roe fishery is highly dependent on market conditions. No commercial fishery for this species exists in Maritimes Region, Gulf Region (Div. 4T), and Arctic waters. With respect to Canadian reported roe landings (in ZIFF), no conversion factor exists to convert these landings to whole (round) weight of females. A factor of 4 is thus currently used for this purpose (Stevenson and Baird 1988). Information on Common Lumpfish roe landings in Atlantic Canada has been published in Stevenson and Baird 1988, Chouinard el at. 1992, Stansbury et al. 1995, Stansbury and Walsh 2002, and Fréchet et al. 2011.

Common Lumpfish roe landings were initially low in Divs. 3P4RS, then significantly increased from 1976 to a peak in 1987 (Fréchet et al 2011; Fig. 88). Over 1987-2000, roe landings were variable, but averaged 2,041 t annually. Roe landings were significantly lower in 2001-03 (548 t average), then increased in 2004, but have since declined to a 79 t annual average over 2009-14. Overall, Div. 4S was a minor contributor, while Subdiv. 3Ps dominated roe landings in 1978-2007 (Fig. 89). In recent years, roe landings were almost exclusively from Div. 4R.

Based on ZIFF data, there was no reported bycatch of whole Common Lumpfish in NAFO Divs. 4RS and Subdiv. 3Pn from 2000-14. For the same period, annual bycatches reported as roe in other directed fisheries were low (Fig. 90). In Div. 4S, less than 5 kg were reported as bycatch in the Greenland Halibut fishery. In Div. 4R, landings of roe were reported in fisheries directing for skate (1.6 t), unknown (0.5 t); American Lobster (*Homarus americanus*; 0.3 t); White Hake (*Urophycis tenuis*; 0.1 t); American Plaice (*Hippoglossoides platessoides*; 0.03 t); Atlantic Halibut (0.008 t); crab (0.02 t); and whelk (0.008 t). In Subdiv. 3Pn, landings of roe were reported in fisheries directing for lobster (0.1 t); skate (0.09 t); American Plaice (0.02 t); White Hake (0.006 t); herring (0.007 t); Snow Crab (Ch*ionoecetes opilio*; 0.004 t); and Winter Flounder (*Pseudopleuronectes americanus*; 0.001 t).

In Divs. 2J3KL, Common Lumpfish roe landings increased over 1970-79, declined to low levels in 1980-84, and then increased dramatically to a peak in 1987 (Stansbury et al. 1995; Fig. 91). Roe landings remained relatively high until 1993, and have since declined to very low levels. Roe landings were variable in Divs. 3KL, and only occasionally reported from Div. 2J; since 2004, the proportion of roe landings from Div. 3K has been increasing (Fig. 92).

In Divs. 3KLOP, the Common Lumpfish-directed gillnet fishery landed the majority of reported roe in 1995-2002, while gillnet fisheries targeting Atlantic Cod and skates (combined) averaged 2% annually (Fig. 93). Since 2003, the directed fishery reported almost all roe landings (395 t annual average). Since 1998 (i.e., when 'month' was recorded in NL fishers' logbooks), roe landings from Divs. 3KL occurred predominantly in June until 2007, when 40% on average were reported annually in July (Fig. 94). Small amounts continued to be landed annually in May. In Subdiv. 3Ps and 3Pn, the majority of Common Lumpfish roe (70% and 84%, respectively) were landed in May over 1998-2006, then mainly occurred in June as of 2007 (74% and 82%, respectively). Negligible amounts were sporadically reported in July.

DFO-NL ZIFF data also indicated that whole Common Lumpfish were occasionally landed. Over 1977-82, landings averaged 121 t annually (Figs. 95, 96). In 2005-14, average annual landings were 7 t. The DFO-MAR ZIFF database contained only 55 records of Common Lumpfish landings for 2002-09, and indicated that bycatch of this species occurred in groundfish fisheries using otter trawls, gillnets, and longlines, in Div. 4X and, to a lesser extent, Div. 5Y.

Although dependent on the percentage of Canadian At-Sea Observer (ASO) coverage of each fishery in each year, NL ASO data from 1983-2014 indicated that most catches of Common Lumpfish occurred in Subdiv. 3Ps (Fig. 97). In 1983-93, bottom otter trawls targeting American Plaice and Atlantic Cod took the majority of observed Common Lumpfish bycatch: annually averaging 18 t (1990 peak of 63 t) and 9 t, respectively (Figs. 98-99). Over 1994-2007, the Common Lumpfish-directed fishery was observed to annually catch 30 t on average (1999 peak of 73 t) with fixed gillnets, while the redfish (*Sebastes* spp.) gillnet fishery averaged 5 t in

1994-2003. Observed catches of Common Lumpfish in directed and bycatch fisheries became negligible by 2008. Changes in these observed catches may be due to annual variation in ASO coverage of fisheries in Subdiv. 3Ps.

The DFO-MAR Canadian At-Sea Observer database (ISDB) was used to investigate Common Lumpfish bycatch in Maritimes groundfish fisheries. The Atlantic Cod fishery showed the largest total weight of observed Common Lumpfish (197,243 t), followed by the redfish (62,315 t) and American Plaice (30,616 t) fisheries (Table 6). In 2005-14, observed Common Lumpfish bycatch in the Atlantic Cod fishery declined to less than 30 t. In the American Plaice fishery, bycatch was rarely observed since 1999 (i.e., four records in 2004). In the redfish fishery, observations sharply declined after 2005. Since 2010, ASOs for two shrimp *(Pandalus* spp.) fisheries have recorded more than 317 t of Common Lumpfish: 223 t with *Pandalus montagui*, and 94 t with *P. borealis*. Observed bycatch of Common Lumpfish has declined in most other fisheries.

The DFO-QC ASO database contained 278 records of Common Lumpfish bycatch in 1999-2014. Overall, more than 90% of observed bycatch was ≤ 3 kg, and most were discarded at sea. In Subdiv. 3Pn, four records were from the redfish fishery, and one from the Atlantic Cod fishery. In Div. 4R, bycatch of Common Lumpfish was observed (in decreasing frequency) in these fisheries: redfish, American Plaice, Atlantic Cod, Witch Flounder (*Glyptocephalus cynoglossus*), Winter Flounder, shrimp, Greenland Halibut, Capelin, and scallop. In Div. 4S, bycatch occurred mostly in shrimp (n=249), Greenland Halibut (n=30), and Atlantic Cod (n=11) fisheries. In Div. 4T, Common Lumpfish were observed (in decreasing frequency) in: cod otter trawls, plaice scottish seines, cod gillnets, redfish trawls, Winter Flounder gillnets, plaice gillnets, cod scottish seines, shrimp trawls (see below), Winter Flounder trawls, and Greenland Halibut gillnets (Fig. 100). Since 2009, bycatch of this species was observed only in the Div. 4T redfish trawl, shrimp trawl, and Greenland Halibut gillnet fisheries, though it is important to note that availability of data was dependent on the percentage of Canadian ASO coverage of each fishery.

In the Gulf of St. Lawrence shrimp fishery (Divs. 4RST), Common Lumpfish bycatch was observed in less than 2% of fishing activities, consisted of ≤1 kg for most hauls, and was discarded at sea, and thus not reported in landings statistics (Bourdages and Marquis 2014). Common Lumpfish bycatch in this fishery primarily occurred around Sept-Iles and Anticosti Island (Fig. 101), and averaged 0.06 t annually (Fig. 102). Overall, this unreported bycatch was estimated to be <1% of the trawlable biomass estimates for Common Lumpfish <31 cm TL in the DFO Gulf of St. Lawrence research survey. Due to use of the Nordmore grate (i.e., a groundfish excluder), Common Lumpfish bycatch in the Divs. 4RST shrimp fishery remains low, and essentially consists of juveniles.

Commercial length frequencies taken in Subdiv. 3Ps over 1995-97 by Canadian ASOs indicated that gillnets caught 30-52 cm Common Lumpfish (Fig. 103, top panel), consisting of 478 females (31-52 cm; 40 cm mode) and 35 males (30-38 cm; 32 cm mode; Fig. 103, bottom panel). In Subdiv. 3Pn and Divs. 4RS over 2004-08, Common Lumpfish-directed gillnets caught 28-52 cm females (40 cm mode; n=3,782), while males were rare and not measured for length (Fig. 104).

Relative fishing mortality (Rel. *F*=[ZIFF-reported commercial Common Lumpfish roe landings]*4/Canadian research survey biomass) was variable and high in Div. 3L over 1996-2006, while remaining low in Div. 3P (except for a peak in 2006), and negligible in Div. 3K (Fig. 105). Relative *F* in Div 3LP decreased to its lowest levels since 2007. For the nGSL, Relative *F* could not be estimated, since there is no reliable biomass index. Catches of mature females in the Common Lumpfish-directed fishery in the nGSL exceed the available population estimates, which are based on the DFO RV survey.

REVIEW OF DESIGNATABLE UNITS

Genetic analyses of ten microsatellite loci were recently conducted by Pampoulie et al. (2014), and three genetic groupings were identified based on geographical location: a Western Atlantic group (Maine–Canada–Greenland); an Eastern Atlantic group (Iceland–Norway); and a Baltic Sea group. This suggests one designatable unit (DU) for Common Lumpfish in Canadian waters, but should be considered with caution due to sampling occurring in only one Canadian location (i.e., variation within Canadian waters was not investigated by this study).

There is some suggestion of discontinuity on the Scotian Shelf in terms of demersal distribution, although pelagic 0-group surveys in the area contradict this.

Rescue of Canadian populations by populations off of Greenland and on Flemish Cap may be possible.

COSEWIC CRITERION

DECLINING TOTAL POPULATION

Overall trends in Common Lumpfish population size in the Northwest Atlantic Ocean are generally unknown. As mentioned previously, DFO research surveys use bottom trawls, and catchability of this species in such gear remains unknown. The semi-pelagic nature of adults, coupled with annual spring spawning migrations, renders standard bottom trawl surveys inappropriate to evaluate population size or trends in abundance and biomass for Common Lumpfish.

In addition, commercial fisheries data are ineffective for determining the population status and trajectory of this species. Annual variability in reported landings of roe is dependent on a number of factors, including the market price for roe, weather conditions, the timing and length of the fishing season, and the occurrence of more lucrative fisheries (e.g., Snow Crab).

THREATS TO ABUNDANCE

Natural and anthropogenic threats to Common Lumpfish abundance include: changes in water temperature and salinity; physical destruction of spawning/nesting habitat; pollution in shallow-water nursery grounds; and directed and bycatch fishing of adults (see Appendix III). To date, no direct evidence exists regarding any linkage between potential threats and Common Lumpfish abundance.

CURRENT PROTECTION AND MANAGEMENT

Common Lumpfish in Canada's EEZ is managed federally under the *Fisheries Act*.

As mentioned previously, Common Lumpfish fishing mortality occurs in gillnet fisheries directing for this species in Divs. 3KLP and Divs. 4RS, and as bycatch in other commercially important groundfish fisheries (e.g., Atlantic Cod, Atlantic Halibut, Monkfish, redfish, skates). Common Lumpfish are fished primarily by Canada, and managed by gear limits, depth restrictions, and a directed fishery limited to May 9-July 21 (i.e., depending on location) with bycatch and small fish protocols (see Appendices).

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REFERENCES

Able, K.W., and Fahay, M.P. 1998. The first year in the life of estuarine fishes in the Middle Atlantic Bight. Rutgers University Press. New Brunswick, NJ. 342 p.

Able, K.W., and Irion, W. 1985. Distribution and reproductive seasonality of snailfishes and lumpfishes in the St. Lawrence River estuary and the Gulf of St. Lawrence. Can. J. Zool. 63: 1622-1628.

Albert, O.T., Torstensen, E., Bertelsen, B., Jonsson, S.T., Pettersen, I.H., and Holst, J.C. 2002. Age-reading of lumpsucker (*Cyclopterus lumpus*) otoliths: dissection, interpretation and comparison with length frequencies. Fish. Res. 55: 239-252.

Bagge, O. 1967. Some preliminary results from tagging of the lumpsucker (*Cyclopterus lumpus*) 1966. ICES C.M. 1967/F 23. 3 p.

Benoît, D., and Bowen, W.D. 1990*a*. Seasonal and geographic variation in the diet of grey seals (*Halichoerus grypus*) in eastern Canada. Pp. 215-226 *in* Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. Edited by W.D. Bowen. Can. Bull. Fish. Aquat. Sci. 222. 306 p.

Benoît, D., and Bowen, W.D. 1990*b*. Summer diet of grey seals (*Halichoerus grypus*) at Anticosti Island, Gulf of St. Lawrence, Canada. Pp. 227-242 *in* Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. *Edited by* W.D. Bowen. Can. Bull. Fish. Aquat. Sci. 222. 306 p.

Benoît, H.P. 2006. Standardizing the southern Gulf of St. Lawrence bottom-trawl survey time series: results of the 2004-2005 comparative fishing experiments and other recommendations for the analysis of the survey data. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/008. 127 p.

Benoît, H.P. 2014. Update on trends in the abundance, distribution and size-composition of snow crab (*Chionoecetes opilio*) in the September multi-species bottom trawl survey of the southern Gulf of St. Lawrence, 1980-2013. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/081. v + 12 p.

Benoît, H.P., and Swain, D.P. 2003. Standardizing the southern Gulf of St. Lawrence bottom-trawl survey time series: adjusting for changes in research vessel, gear and survey protocol. Can. Tech. Rep. Fish. Aquat. Sci. 2505: iv + 95 p.

Bigelow, H.B., and Schroeder, W.C. 1953. Fishes of the Gulf of Maine. Fishery Bull. Fish. Wildl. Serv. 74(53). 577 p.

Bishop, C.A. 1994. Revisions and additions to stratification schemes used during research vessel surveys in NAFO Subareas 2 and 3. NAFO Sci. Coun. Res. Doc. 94/043. 23 p.

Blackwood, G. 1982. Contributions to the biology of the lumpfish (*Cyclopterus lumpus*) with reference to the Newfoundland lumpfish roe fishery. Thesis (B.Sc). Memorial University of Newfoundland, St. John's, Newfoundland, Canada. 46 p.

Blackwood, G. 1983. Lumpfish roe fishery development in Newfoundland, 1982-83. Newfoundland Department of Fisheries, Industry Support Services, Development Report no. 31. 29 p.

Bleakney, J.S., and McAllister, D.E. 1973. Fishes stranded during extreme low tides in Minas Basin, Nova Scotia. Can. Field-Nat. 87: 371-376.

Bourdages, H., and Marquis, M.C. 2014. Assessment of Northern Shrimp stocks in the Estuary and Gulf of St. Lawrence in 2013: commercial fishery data. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/051. iv + 90 p.

Bourdages, H., and Ouellet, J.-F. 2011. Geographic distribution and abundance indices of marine fish in the northern Gulf of St. Lawrence (1990–2009). Can. Tech. Rep. Fish. Aquat. Sci. 2963. vi + 171 p.

Bourdages, H., Savard, L., Archambault, D., and Valois, S. 2007. Results from the August 2004 and 2005 comparative fishing experiments in the northern Gulf of St. Lawrence between the CCGS Alfred Needler and the CCGS Teleost. Can. Tech. Rep. Fish. Aquat. Sci. 2750. ix + 57 p.

Bourdages, H., Brassard, C., Desgagnés, M., Galbraith, P., Gauthier, J., Lambert, J., Légaré, B., Parent, E., and Schwab, P. 2015. Preliminary results from the groundfish and shrimp multidisciplinary survey in August 2014 in the Estuary and northern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/115. v + 96 p.

Brodie, W.B., and Stansbury, D. 2007. A brief description of Canadian multispecies surveys in SA2 + Divisions 3KLMNO from 1995-2006. NAFO Sci. Coun. Res. Doc. 07/18, Ser. No. N5366. 24 p.

Brown, J.A. 1986. The development of feeding behaviour in the lumpfish, *Cyclopterus lumpus*. J. Fish Biol. 29*a*: 171-178.

Brown, J.A., Somerton, D.C., Methven, D.A., and Watkins, J.R. 1992. Recent advances in lumpfish *Cyclopterus lumpus* and ocean pout *Macrozoarces americanus* larviculture. J. World Aquacult. Soc. 23: 271-276.

Chadwick, E.M.P., Brodie, W., Clark, D., Gascon, D., Hurlbut, T. 2007. History of annual multi-species trawl surveys on the Atlantic Coast of Canada/Historique des relevés de chalut multi-spécifiques annuels sur la côte Atlantique du Canada. Atl. Zonal Monit. Program Bulletin No. 6 (April 2007): 25-42.

Chouinard, G. A., Hurlbut, T., Morin, B., Baird, J., and Bishop, C. 1992.The lumpfish (*Cyclopterus lumpus*) resource in Atlantic Canada. Can. Atl. Fish. Sci. Advis. Committee Res. Doc. 92/106.

Chumakov, A.K., and Podrazhanskaya, S.G. 1986. Feeding of Greenland Halibut (*Reinhardtius hippoglossoides*) in the Northwest Atlantic. NAFO Sci. Coun. Studies 10: 47-52.

Claytor, R., Clark, D., McIntyre, T., Stone, H., Cook, A., Harris, L., Simon, J., Emery, P., and Hurley, P. 2014. Review of Surveys Contributing to Groundfish Assessments with Recommendations for an Ecosystem Survey Program in the Maritimes Region. Can. Tech. Rep. Fish. Aquat. Sci. 3083. 90 p.

Collette, B.B., and Klein-MacPhee, G. (eds.). 2002. Bigelow and Schroeder's fishes of the Gulf of Maine (3rd Edition). Smithsonian Institution Press, Washington, D.C. xxxiii + 748 p.

Collins, M.A.J. 1976. The lumpfish (*Cyclopterus lumpus* L.) in Newfoundland waters. Can. Field-Nat. 90: 64-67.

Collins, M.A.J. 1978. Experiments on the hatching period of the eggs of the lumpfish *Cyclopterus lumpus* L. in Newfoundland waters. Nat. Can. 105: 169-171.

Cox, P., and Anderson, M. 1922. A study of the lumpfish *Cyclopterus lumpus* L. Contrib. Can. Biol. N.S. 1: 1-20.

Daborn, G.R., and Gregory, R.S. 1983. Occurrence, distribution, and feeding habits of juvenile lumpfish, *Cyclopterus lumpus* L. in the Bay of Fundy. Can. J. Zool. 61: 797-801.

Davenport, J. 1985. Synopsis of biological data on the lumpsucker (*Cyclopterus lumpus* Linnaeus, 1758). FAO Fish. Synop. no. 147. 31 p.

Davenport, J., and Kjørsvik, E. 1986. Buoyancy in the lumpsucker *Cyclopterus lumpus*. J. Mar. Biol. Assoc. UK. 66: 159-174.

DFO. 2006. Assessment of Lumpfish in the Gulf of St. Lawrence (3Pn, 4RST) in 2005. DFO Can. Sci. Advis. Sec., Sci., Advis. Rep. 2006/034.

Doubleday, W.G. 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO Sci. Coun. Studies 2. 55 p.

Dutil J.-D, Proulx, S., Chouinard, P., Borcard, D., Laurian, C., Tamdrari H., and Nozères, C. 2013. A standardized database to describe and classify offshore benthic marine habitats and its use for designating the critical habitat of species at risk. Can. Manuscr. Rep. Fish. Aquat. Sci., 3014. vi + 347 p.

Eriksen, E., Durif, C.M., and Prozorkevich, D. 2014. Lumpfish (*Cyclopterus lumpus*) in the Barents Sea: development of biomass and abundance indices, and spatial distribution. ICES J. Mar. Sci. 71: 2398-2402.

Fahay, M.P. 2007. Early stages of Fishes in the western North Atlantic Ocean (Davis Strait, Southern Greenland and Flemish Cap to Cape Hatteras) v.2: Scorpaeniformes through Tetraodontiformes. Northwest Atlantic Fisheries Organization, Dartmouth, Nova Scotia, Canada. 765 p.

Fréchet, A., Gauthier, J., Schwab, P., Collier, F., and Spingle, J. 2006. Tagging of Lumpfish (*Cyclopterus lumpus*) in the Northern Gulf of St. Lawrence from 2004 to 2006. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/084. ii + 15 p.

Fréchet, A., Gauthier, J., Schwab, P., Beaudoin, M., Collier, F., and Way, M. 2011. Assessment of lumpfish (*Cyclopterus lumpus*) in the Gulf of St. Lawrence (3Pn, 4RST) in 2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/119. vii + 33 p.

Froese, R. and Pauly, D. (eds.). 2015. FishBase (accessed August 2015).

Gotceites, V., Fraser, S., and Brown, J.A. 1997. Use of eelgrass (*Zostera marina*) by juvenile Atlantic cod (*Gadus morhua*). Can. J. Fish. Aquat. Sci. 54: 1306-1319.

Goulet, D. 1985. Reproductive behavior, spawning success, and mate choice of the lumpfish, *Cyclopterus lumpus* L., in Newfoundland. Thesis (M.Sc.). Memorial University of Newfoundland, St. John's, Newfoundland, Canada. 72 p.

Goulet, D., and Green, J.M. 1988. Reproductive success of the male lumpfish (*Cyclopterus lumpus* L.) (Pisces: Cyclopteridae): evidence against female mate choice. Can. J. Zool. 66(11): 2513-2519.

Goulet, D., Green, J.M., and Shears, T.H. 1986. Courtship, spawning, and parental care behavior of the lumpfish, *Cyclopterus lumpus* L., in Newfoundland. Can. J. Zool. 64(6): 1320-1325.

Grant, S.M. 2001. Alternative harvesting strategies for lumpfish: the feasibility of collecting lumpfish roe using non-lethal techniques. Report submitted by LGL Environmental Associates Ltd to the Fisheries Diversification Program, Newfoundland Department of Fisheries and Aquaculture, St. John's, Newfoundland, Canada. 63 p.

Grant, C., et Provencher, L. 2007. Caractérisation de l'habitat et de la faune des herbiers de Zostera marina (L.) de la péninsule de Manicouagan (Québec). Rapp. tech. can. sci. halieut. aquat. 2772. viii + 65 p.

Hammill, M.O., Stenson, G.B., Proust, F., Carter, P. and McKinnon, D. 2007. Feeding by grey seals in the Gulf of St. Lawrence and around Newfoundland. North Atl. Marine Mammal Commission Sci. Publ. 6:135-152.

Healey, B.P., and Brodie, W.B. 2009. Brief notes on the execution of Canadian multi-species surveys in 2007 and 2008. NAFO Sci. Coun. Res. Doc. 09/12, Ser. No. N5639. 26 p.

Hedeholm, R., Blicher, M.E., and Grønkjær, P. 2014. First estimates of age and production of lumpsucker (*Cyclopterus lumpus*) in Greenland. Fish. Res. 149: 1-14.

Heuch, P.A., Øines, Ø., Knutsen, J.A., and Schram, T.A. 2007. Infection of wild fishes by the parasitic copepod *Caligus elongatus* on the south east coast of Norway. Dis. Aquat. Org. 77: 149-158.

Hurlbut, T., and Clay, D. 1990. Protocols for research vessel cruises within the Gulf Region (demersal fish) (1970-1987). Can. Manuscr. Rep. of Fish. Aquat. Sci. 2082. 143 p.

Ingólfsson, A., and Kristjánsson, B.K. 2002. Diet of juvenile Lumpsucker *Cyclopterus lumpus* (Cyclopteridae) in floating seaweed: effects of ontogeny and prey availability. Copeia 2: 472-476.

Kennedy, J., Jónsson, S.T., Kasper, J.M., and Ólafsson, H.G. 2014. Movements of female lumpfish (*Cyclopterus lumpus*) around Iceland. ICES J. Mar. Sci. doi:10.1093/icesjms/fsu170.

Kulka, D.W., and Templeman, N. 2013. Distribution and habitat associations of selected demersal fish species in the Laurentian Channel and Laurentian Area of Interest (AOI). DFO Can. Sci. Advis. Sec. Res. Doc. 2013/099. v + 44 p.

Lacroix, G.L., and Knox, D. 2005. Distribution of Atlantic salmon (*Salmo salar*) post-smolts of different origins in the Bay of Fundy and Gulf of Maine and evaluation of factors affecting migration, growth and survival. Can. J. Fish. Aquat. Sci. 62: 1363–1376.

Lee, E.M., and Christian, J.R. 2002. Alternate Harvesting Strategies for Lumpfish: Non-Lethal Extraction of Lumpfish Roe. LGL Environmental Associates Ltd., St. John's, Newfoundland, Canada. 45 p.

Margolis, L., and Arthur, J.R. 1979. Synopsis of the parasites of fishes of Canada. Bull. Fish. Res. Bd. Can. 199. 269 p.

McCallum, B.R., and Walsh, S.J. 1996. Groundfish survey trawls used at the Northwest Atlantic Fisheries Centre, 1971-present. NAFO Sci. Coun. Studies 29: 93-103.

McKenzie, R.A. 1959. Marine and freshwater fishes in the Miramichi River and Estuary, New Brunswick. J. Fish. Res. Board Can. 16: 807-833.

Mochek, A.D. 1973. Spawning behaviour of the lumpsucker *Cyclopterus lumpus* L. J. Ichthyol. 13: 615-619.

Moring, J.R. 1989. Food habits and algal associations of juvenile lumpfish, *Cyclopterus lumpus* L., in intertidal waters. Fish. Bull. 87: 233-237.

Moring, J.R., and Moring, S.W. 1991. Short-term movements of larval and juvenile lumpfish, *Cyclopterus lumpus* L., in tidepools. J. Fish Biol. 38: 845-850.

Muus, B.J. and Nielsen, J.G. 1999. Sea fish. Scandinavian Fishing Year Book, Hedehusene, Denmark. 340 p.

Nellis, P., Dorion, D., Pereira, S., Ellefsen, H.-F., and Lemay, M. 2012. Monitoring of vegetation and fish in six eelgrass beds in Quebec (2005–2010). Can. Tech. Rep. Fish. Aquat. Sci. 2985. ix+96 p.

O'Connell, M.F., Andrews, C.W., O'Brien, J.P., and Dawe, E.G. 1984. Aspects of the ecology of the fishes of Holyrood Pond: a coastal lake with occasional access to the sea located in St. Mary's Bay, Newfoundland. Int. Rev. Gesamt. Hydrobiol. 69: 333-360.

Øines, Ø., and Heuch, P.A. 2007. *Caligus elongatus* Nordmann genotypes on wild and farmed fish. J. Fish. Dis. 30: 81–91.

Øines, Ø., Simonsen, J.H., Knutsen, J.A., and Heuch, P.A. 2006. Host preference of adult *Caligus elongatus* Nordmann in the laboratory and its implications for Atlantic cod aquaculture. J. Fish. Dis. 29: 167–174.

Pampoulie, C., Skirnisdottir, S., Olafsdottir, G., Helyar, S.J., Thorsteinsson, V., Jónsson, S.T., Fréchet, A., Durif, C.M.F., Sherman, S., Lampart-Kałuzniacka, M., Hedeholm, R., Ólafsson, H.G., Daníelsdóttir, A.K., and Kasper, J.M. 2014. Genetic structure of the lumpfish *Cyclopterus lumpus* across the North Atlantic. ICES J. Mar. Sci. 71: 2390-2397.

Perry, R.I., and Smith, S.J. 1994. Identifying habitat associations of marine fishes using survey data: an application to the NW Atlantic. Can. J. Fish. Aquat. Sci. 51: 589-602.

Roe, H.S.J. 1969. The food and feeding habits of the Sperm Whales (*Physeter catodon* L.) taken off the West Coast of Iceland. J. Cons. Inter. Pour l'Explor. Mer. 33: 93-102.

Schopka, S.A. 1974. Preliminary results from tagging of lumpsucker (*Cyclopterus lumpus*) in Icelandic waters 1971-1973. ICES CM 1974/F: 18. Demersal Fish (Northern) Committee. 6 p.

Scott, W.B., and Scott, M.G. 1988. Atlantic fishes of Canada. Can. Bull. Fish. Aquat. Sci. no. 219. 731 p.

Shears, T.H. 1980. Post spawning behaviour of male lumpfish, *Cyclopterus lumpus*, Cyclopteridae, in Conception Bay, Newfoundland. Honours Theses (B.Sc.). Memorial University of Newfoundland, St. John's, Newfoundland, Canada. 55 p.

Sheehan, T.F., Reddin, D.G., Chaput, G., and Renkawitz, M.D. 2012. SALSEA North America: a pelagic ecosystem survey targeting Atlantic salmon in the Northwest Atlantic. ICES J. Mar. Sci. 69: 1580–1588.

Simpson, M.R., and Miri, C.M. 2013. An assessment of White Hake (*Urophycis tenuis*, Mitchill 1815) in NAFO Divisions 3N, 3O, and Subdivision 3Ps. NAFO Sci. Coun. Res. Doc. 13/030. 28 p.

Simpson, M.R., Sherwood, G.D., Mello, L.G.S., Miri, C.M., and Kulka, D.W. 2013. Feeding habits and trophic niche differentiation in three species of wolffish (*Anarhichas* sp.) inhabiting Newfoundland and Labrador waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/056. v + 29 p.

Smith, S.J. 1996. Analysis of data from bottom trawl surveys. *In* Assessment of groundfish stocks based on bottom trawl survey results. Edited by H. Lassen. NAFO Sci. Coun. Studies 28: 25–53.

Smith, S.J., and Somerton, G.D. 1981. STRAP: A user-oriented computer analysis system for groundfish research vessel survey data. Can. Tech. Rep. Fish. Aquat. Sci. 1030. iv + 66p.

Stevenson, S.C., and Baird, J.W. 1988. The fishery for lumpfish (*Cyclopterus lumpus*) in Newfoundland waters. Can. Tech. Rep. Fish. Aquat. Sci. 1595. iv + 26p.

Stansbury, D. E., Murphy, E. F., and Bishop, C. A. 1995 An update of stock status of 3KLP lumpfish. DFO Atl. Res. Doc. 95/65.

Stansbury, D. E., and Walsh, D. 2002. Lumpfish in NAFO Division 3P. DFO Atl. Res. Doc. 02/95.

Templeman, W., Hodder, V.M., and Fleming, A.M. 1976. Infection of lumpfish (*Cyclopterus lumpus*) with larvae and of Atlantic cod (*Gadus morhua*) with adults of the Copepod, *Lernaeocera branchialis*, in and adjacent to the Newfoundland area, and inferences therefrom on Inshore–Offshore Migrations of Cod. J. Fish. Res. Bd. Can. 33: 711-731.

Thorsteinsson, V. 1981. The ageing validation of the lumpsucker (*Cyclopterus lumpus*) and the age composition of the lumpsucker in Icelandic lumpsucker fisheries. ICES CM 1981/G: 58. 26 p.

Vandendriessche, S., Messiaen, S., Oflynn, S., Vincx, M., and Degraer, S. 2007. Hiding and feeding in floating seaweed: Floating seaweed clumps as possible refuges or feeding grounds for fishes. Estuar. Coast. Shelf Sci. 71: 691-703.

Walsh, S.J., and McCallum, B.R. 1996. Performance of the Campelen 1800 Shrimp Trawl during the 1995 Northwest Atlantic Fisheries Centre autumn groundfish survey. NAFO Sci. Coun. Studies 29: 105-116.

Wienerroither, R., Johannesen, E., Dolgov, A., Byrkjedal, I., Bjelland, O., Drevetnyak, K., Eriksen, K.B., Høines, Å., Langhelle, G., Langøy, H., Prokhorova, T., Prozorkevich, D., and Wenneck, T. 2011. Atlas of the Barents Sea Fishes. IMR-PINRO Joint Report Series 1-2011. ISSN 1502-8828. 272 p.

Wienerroither, R., Johannesen, E., Dolgov, A., Byrkjedal, I., Aglen, A., Bjelland, O., Drevetnyak, K., Eriksen, K.B., Høines, Å., Langhelle, G., Langøy, H., Murashko, P., Prokhorova, T., Prozorkevich, D., Smirnov, O., and Wenneck, T. 2013. Atlas of the Barents Sea Fishes based on the winter survey. IMR-PINRO Joint Report Series 2-2013. ISSN 1502-8828. 220 p.

Zhitenev, A.N. 1970. Ecological and morphological features of the reproduction of the lumpsucker (Cyclopterus *lumpus* L.). J. Ichthyol. 10: 77-83.

APPENDIX I - FIGURES

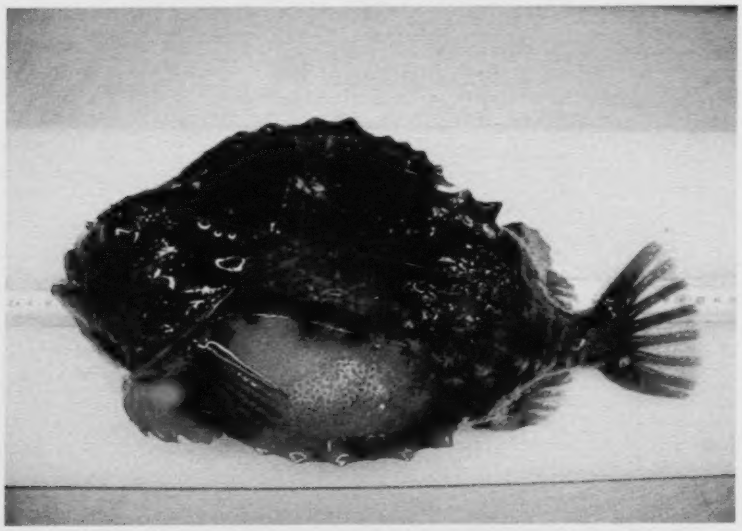


Figure 1A. Common Lumpfish adult male, displaying courtship colouration (Photo credit: DFO-Quebec Region).

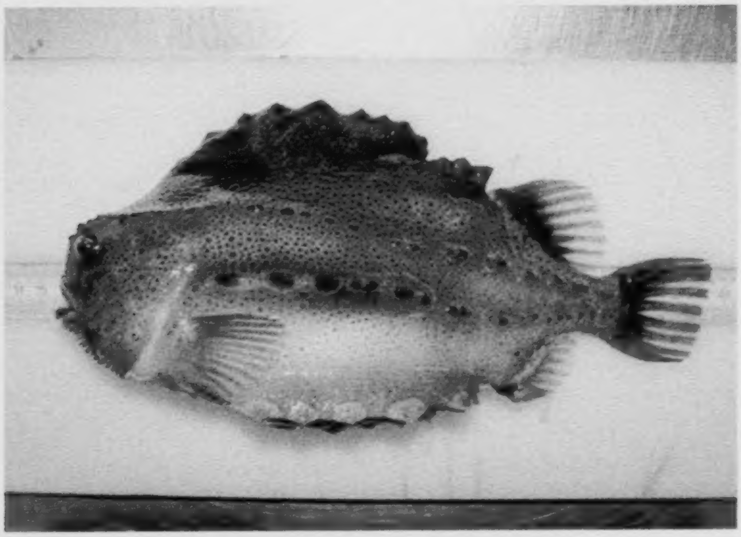


Figure 1B. Common Lumpfish adult female (Photo credit: DFO-Quebec Region).

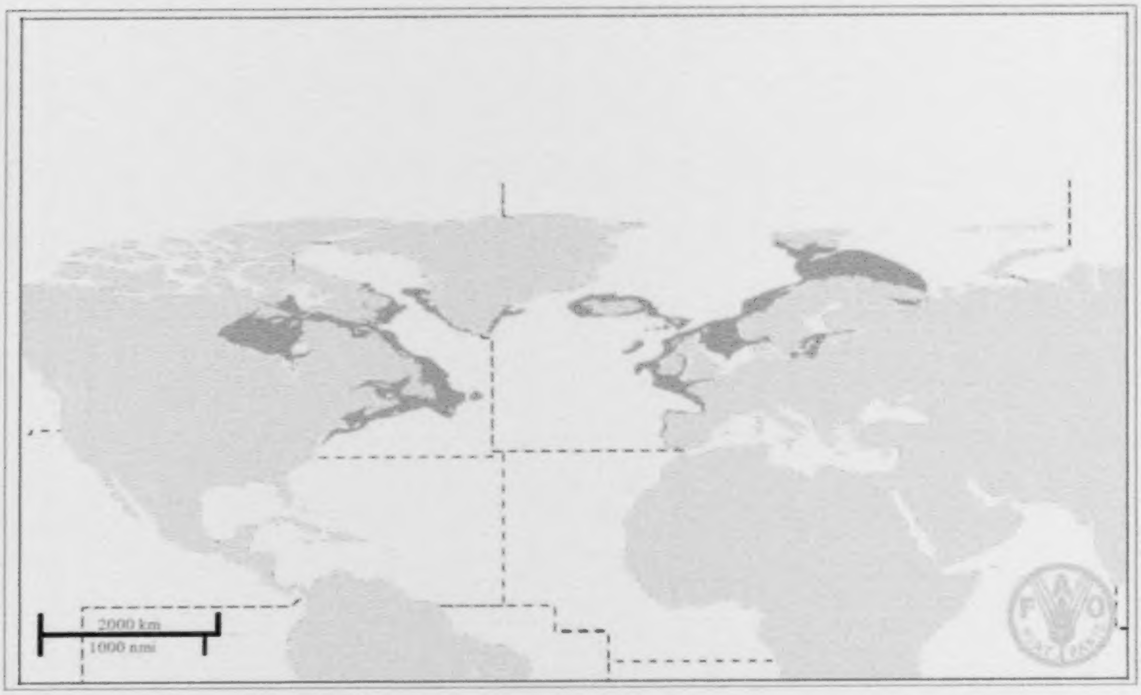

2000 km
1000 nmi

Figure 2. Map of the global distribution of Common Lumpfish. Source: FAO species profile.

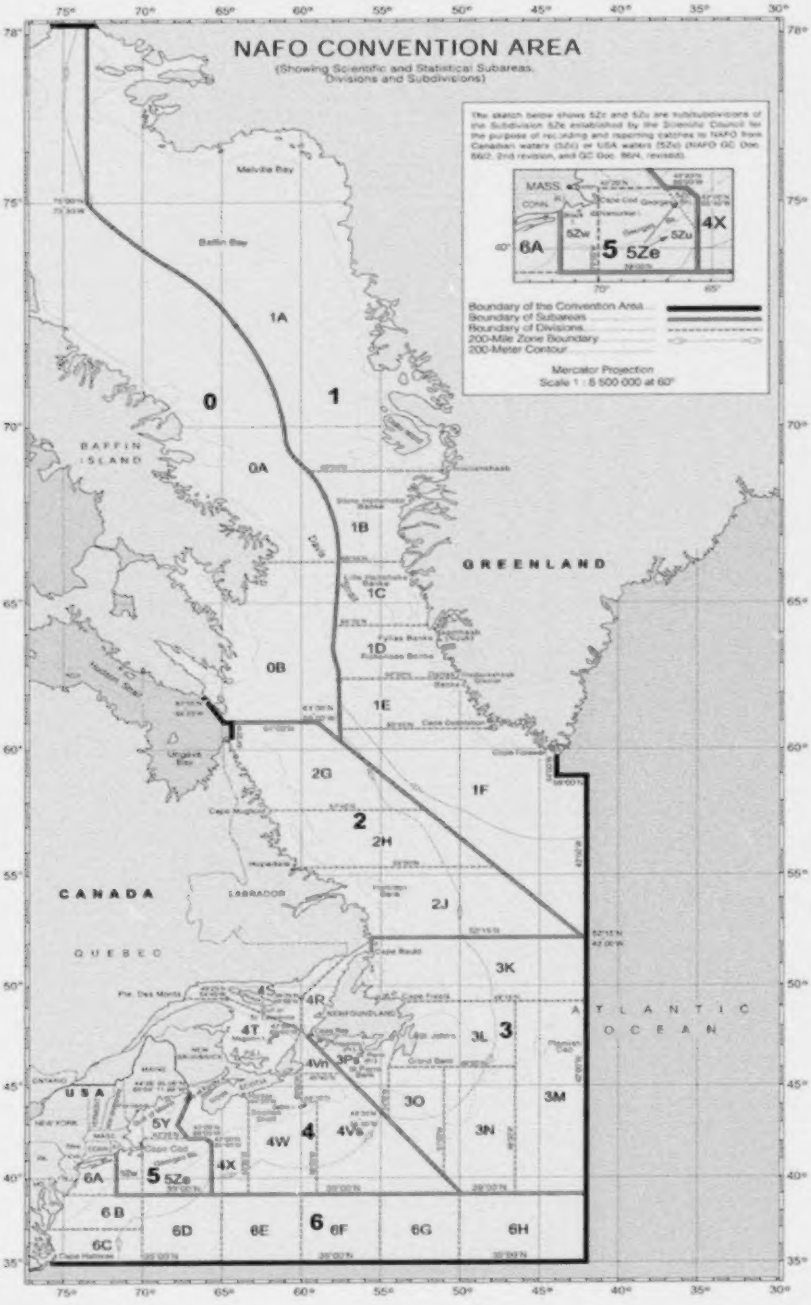

NAFO CONVENTION AREA
(Showing Scientific and Statistical Subareas, Divisions and Subdivisions)
0
1
0A
0B
1A
1B
1C
1D
1E
1F
2
2G
2H
2J
3
3K
3L
3M
3N
3O
3Ps
4
4R
4S
4T
4Vn
4Vs
4W
4X
5
5Y
5Ze
6
6A
6B
6C
6D
6E
6F
6G
6H
GREENLAND
BAFFIN ISLAND
CANADA
QUEBEC
LABRADOR
U S A
ATLANTIC OCEAN
Baffin Bay
Melville Bay
Boundary of the Convention Area
Boundary of Subareas
Boundary of Divisions
200-Mile Zone Boundary
200-Meter Contour
Mercator Projection
Scale 1 : 6 500 000 at 60°
75°
70°
65°
60°
55°
50°
45°
40°
35°
30°
78°

Figure 3. Map of Canadian Atlantic and Arctic waters mentioned in the text. Canada's Exclusive Economic Zone is delineated by the thin blue line (emphasized with fish outlines), NAFO Subareas by thick red lines, NAFO Divisions by thick dashed red lines, and a 200-meter contour by the thin blue dashed line.

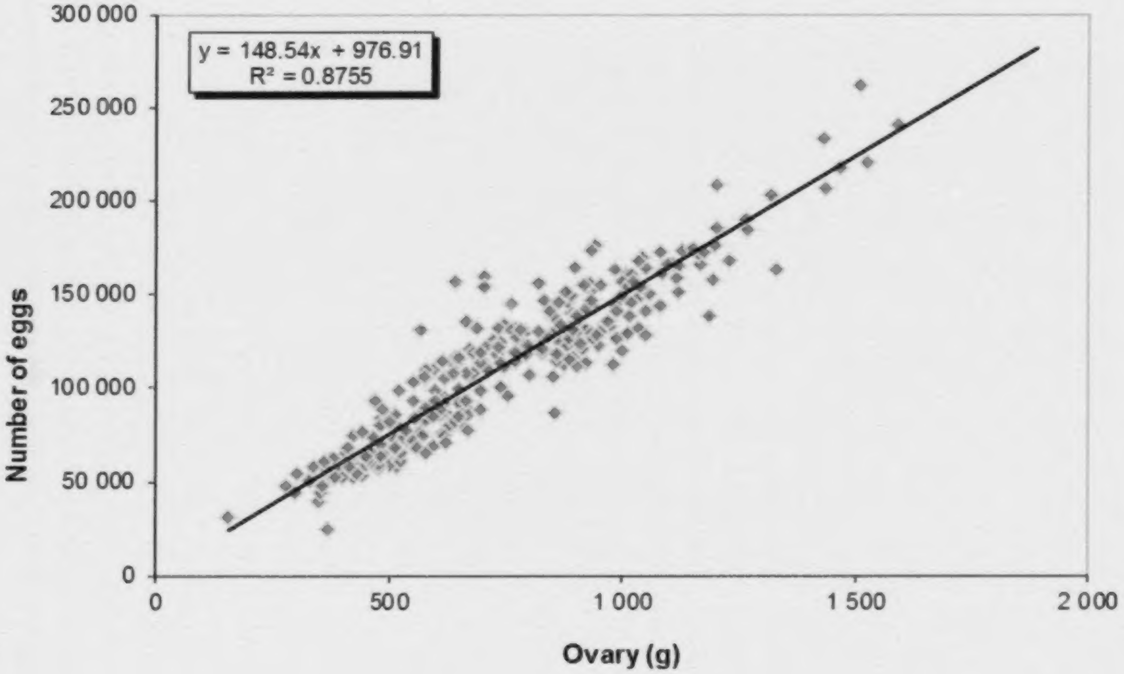


Figure 4. Relationship between egg number and ovary weight (g) for Common Lumpfish 30-48cm TL from Divs. 4RS and Subdiv. 3Pn in 2004-05.

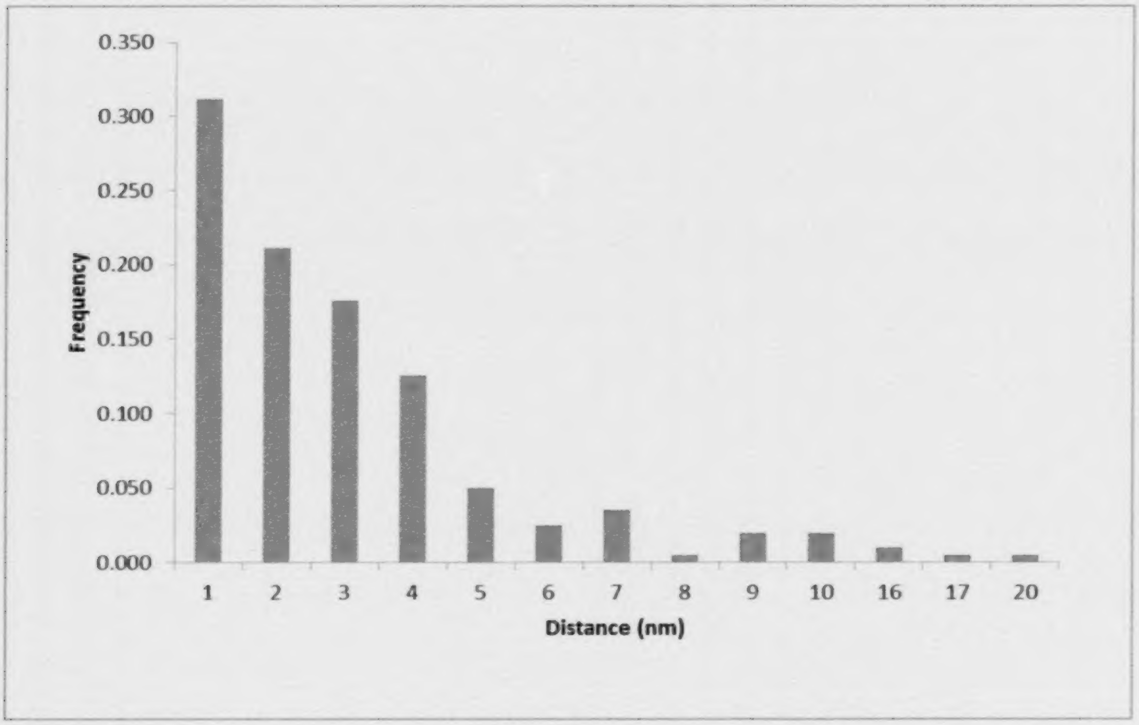


Figure 5. Distance from tagging site of recaptured Common Lumpfish in Newfoundland waters over May 1988-June 1989.

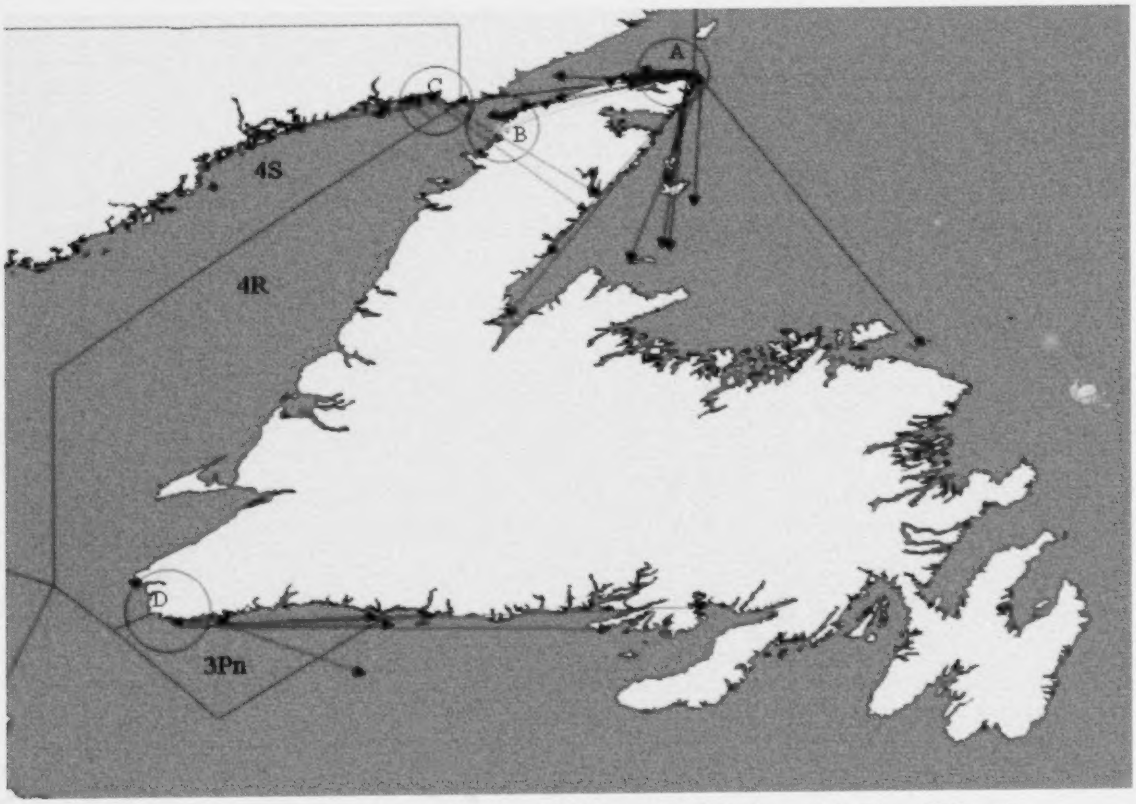

A
C
B
4S
4R
D
3Pn

Figure 6. Common Lumpfish movements from 2004-08 for individuals tagged in Divs. 4RS and Subdiv. 3Pn.

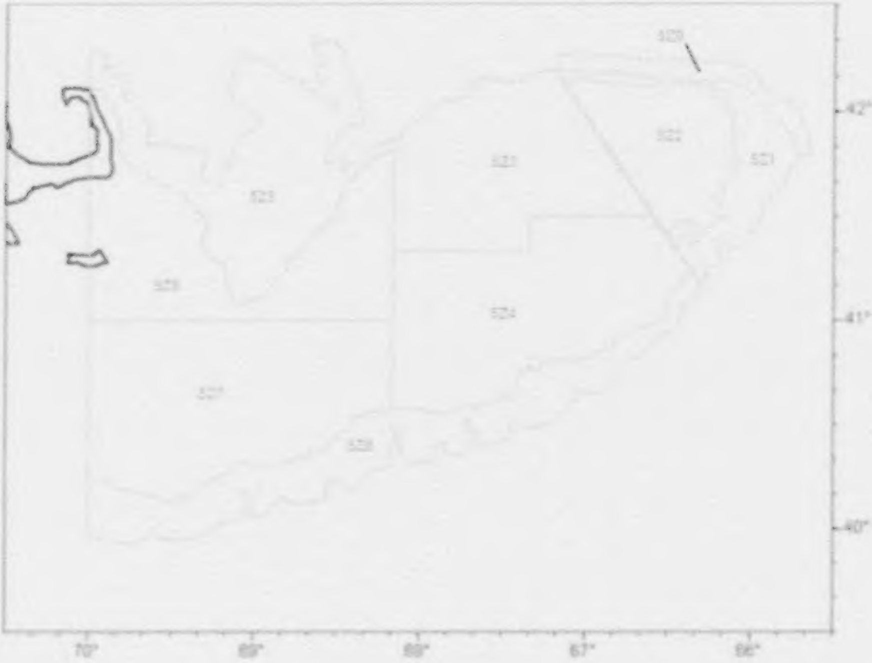

5Z9
5Z2
5Z1
5Z3
5Z5
5Z6
5Z4
5Z7
5Z8
42°
41°
40°
70°
69°
68°
67°
66°

Figure 7. Stratification scheme used for the Georges Bank winter research survey, 1986-2014.

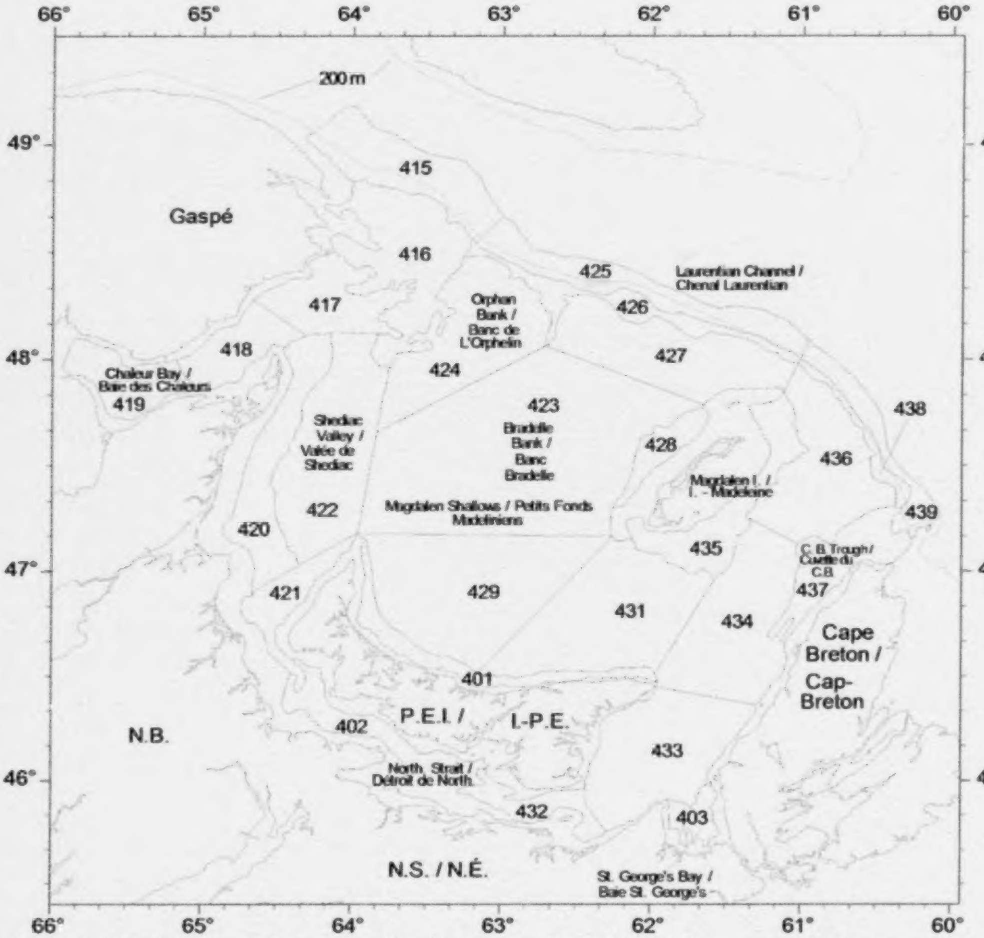
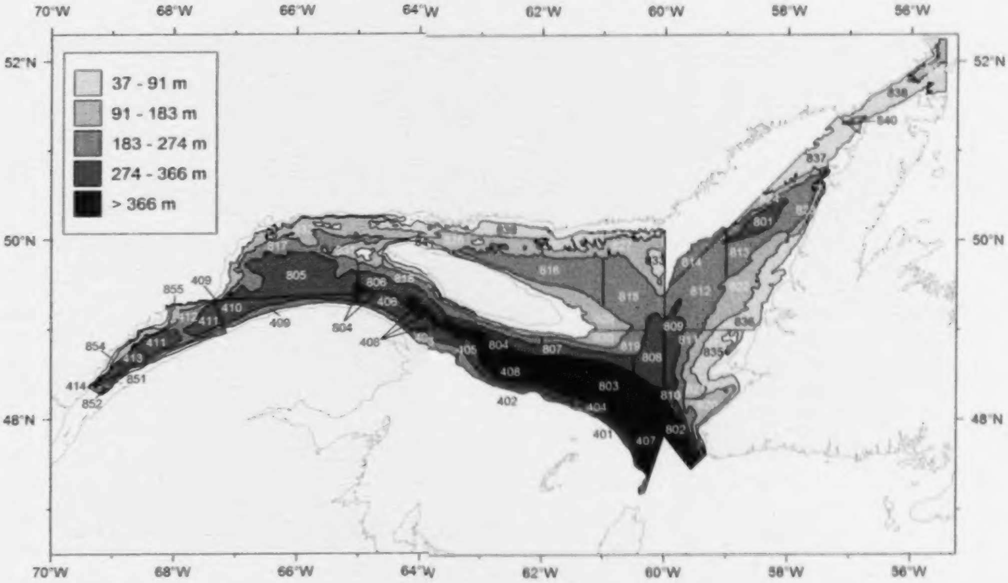
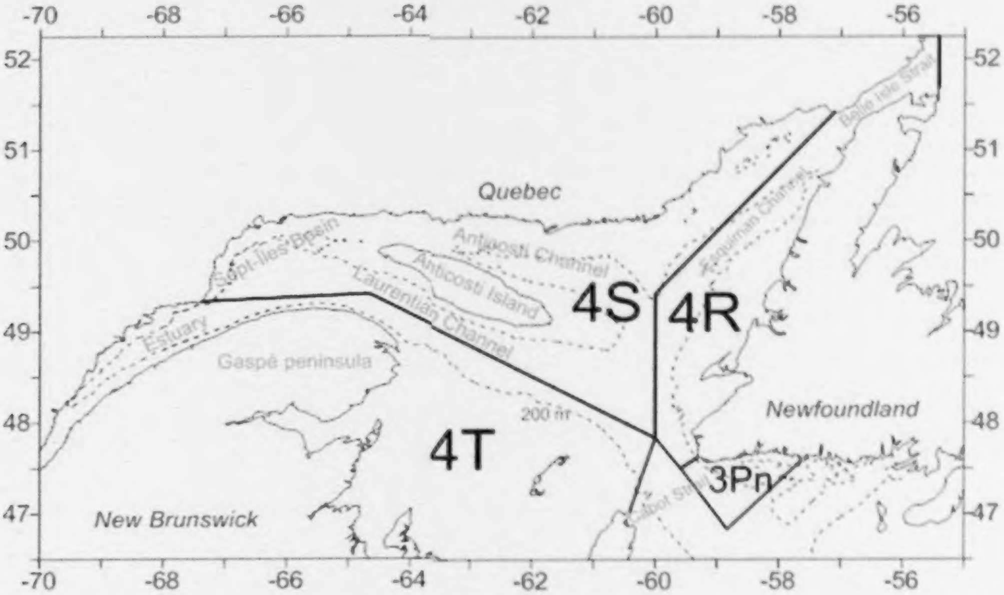

66°
65°
64°
63°
62°
61°
60°
49°
48°
47°
46°
200 m
415
Gaspé
416
425
Laurentian Channel / Chenal Laurentien
417
Orphan Bank / Banc de L'Orphelin
426
418
427
Chaleur Bay / Baie des Chaleurs
419
424
423
438
Shediac Valley / Vallée de Shediac
Bradelle Bank / Banc Bradelle
428
436
Magdalen I. / I. - Madeleine
422
Magdalen Shallows / Petits Fonds Madeliniens
439
420
435
C.B. Trough / Cuvette du C.B.
437
421
429
431
434
Cape Breton / Cap-Breton
401
P.E.I. / I.-P.E.
402
N.B.
433
North. Strait / Détroit de North.
432
403
N.S. / N.É.
St. George's Bay / Baie St. George's

Figure 8. Stratification scheme used for the southern Gulf of St. Lawrence DFO research survey, 1971-2014.



37 - 91 m
91 - 183 m
183 - 274 m
274 - 366 m
> 366 m
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
52°N
50°N
48°N

Figure 9A. Stratification scheme used for the groundfish and shrimp research survey in the Estuary and northern Gulf of St. Lawrence.



-70
-68
-66
-64
-62
-60
-58
-56
52
51
50
49
48
47
Quebec
Sept-Iles Basin
Anticosti Channel
Anticosti Island
Laurentian Channel
Esquiman Channel
Belle Isle Strait
Estuary
Gaspé peninsula
200 m
4S
4R
4T
3Pn
Newfoundland
New Brunswick
Cabot Strait

Figure 9B. Gulf of St. Lawrence with NAFO Divisions and locations cited.

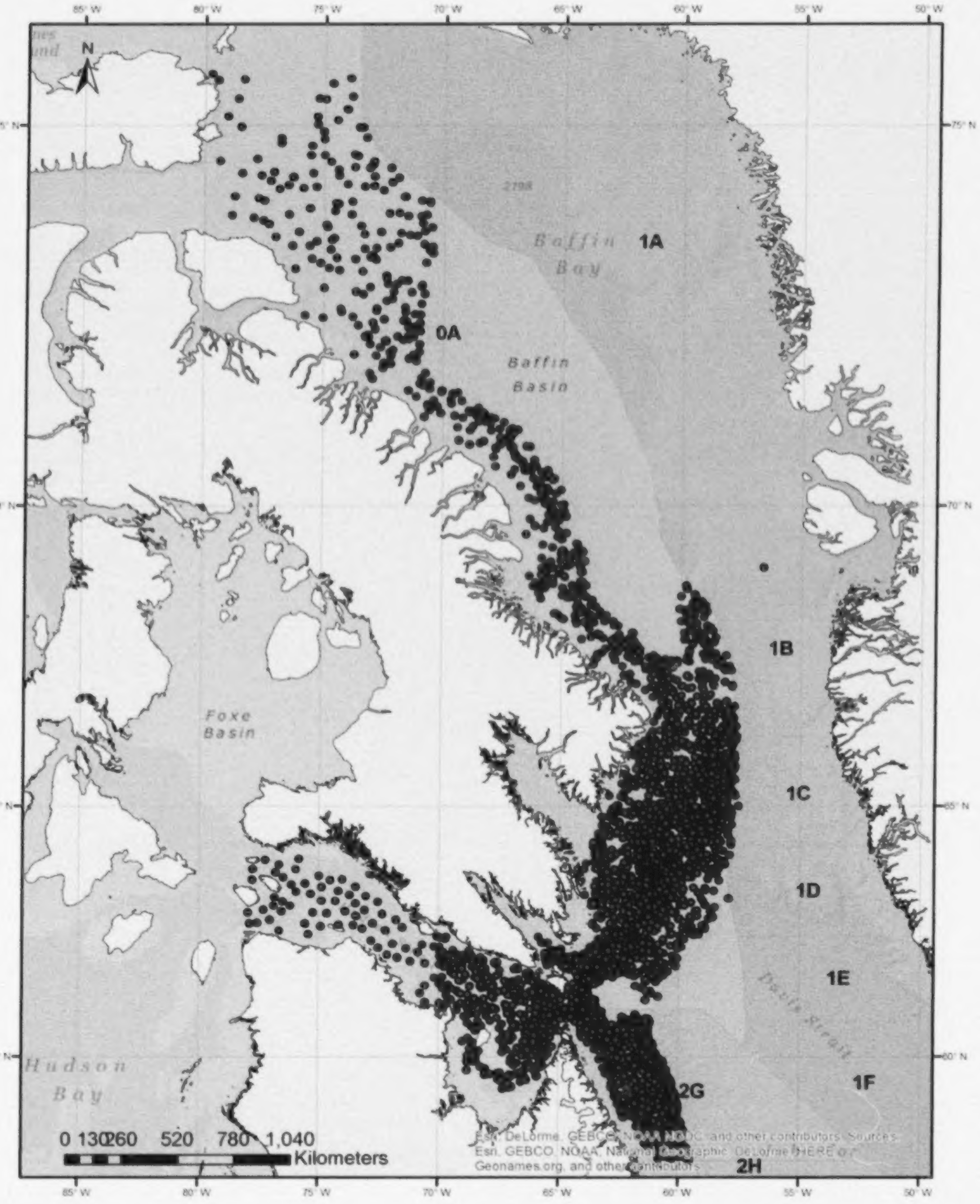

N
85° W
80° W
75° W
70° W
65° W
60° W
55° W
50° W
75° N
70° N
65° N
60° N
2798
Baffin Bay
1A
0A
Baffin Basin
1B
Foxe Basin
1C
1D
1E
Davis Strait
Hudson Bay
2G
1F
2H
0 130 260 520 780 1,040 Kilometers
Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors, Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors

Figure 10. Survey areas for DFO and Northern Shrimp Research Foundation stock assessment and ecosystem monitoring. Red dots indicate starting coordinates for bottom trawl sets. Data are combined over surveys conducted from 1999-2014.

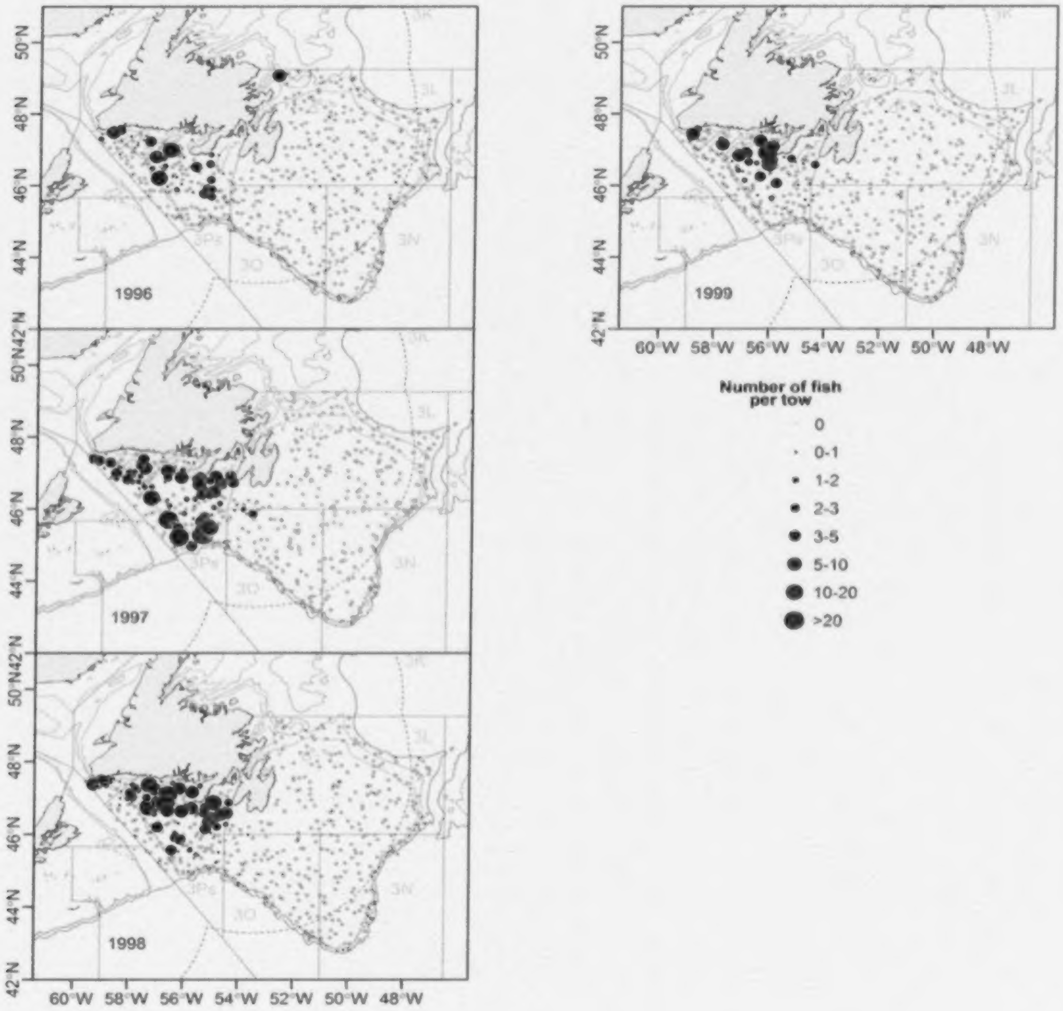

1996
1997
1998
1999
3K
3L
3N
3O
3Ps
50°N
48°N
46°N
44°N
42°N
60°W
58°W
56°W
54°W
52°W
50°W
48°W
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 11. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-NL spring Campelen research surveys, 1996-99.

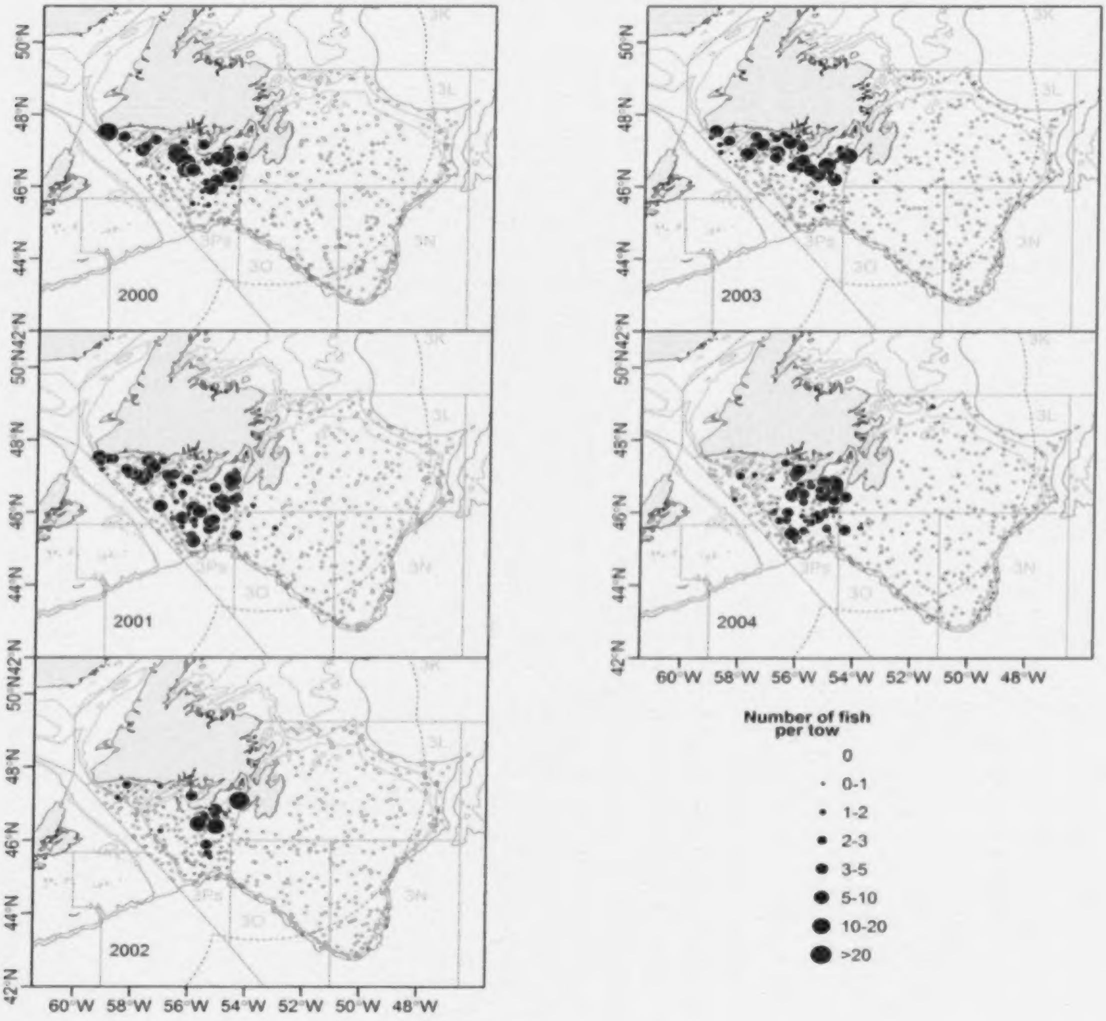

2000
2001
2002
2003
2004
3K
3L
3N
3O
3Ps
50°N
48°N
46°N
44°N
42°N
60°W
58°W
56°W
54°W
52°W
50°W
48°W
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 12. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-NL spring Campelen research surveys, 2000-04.

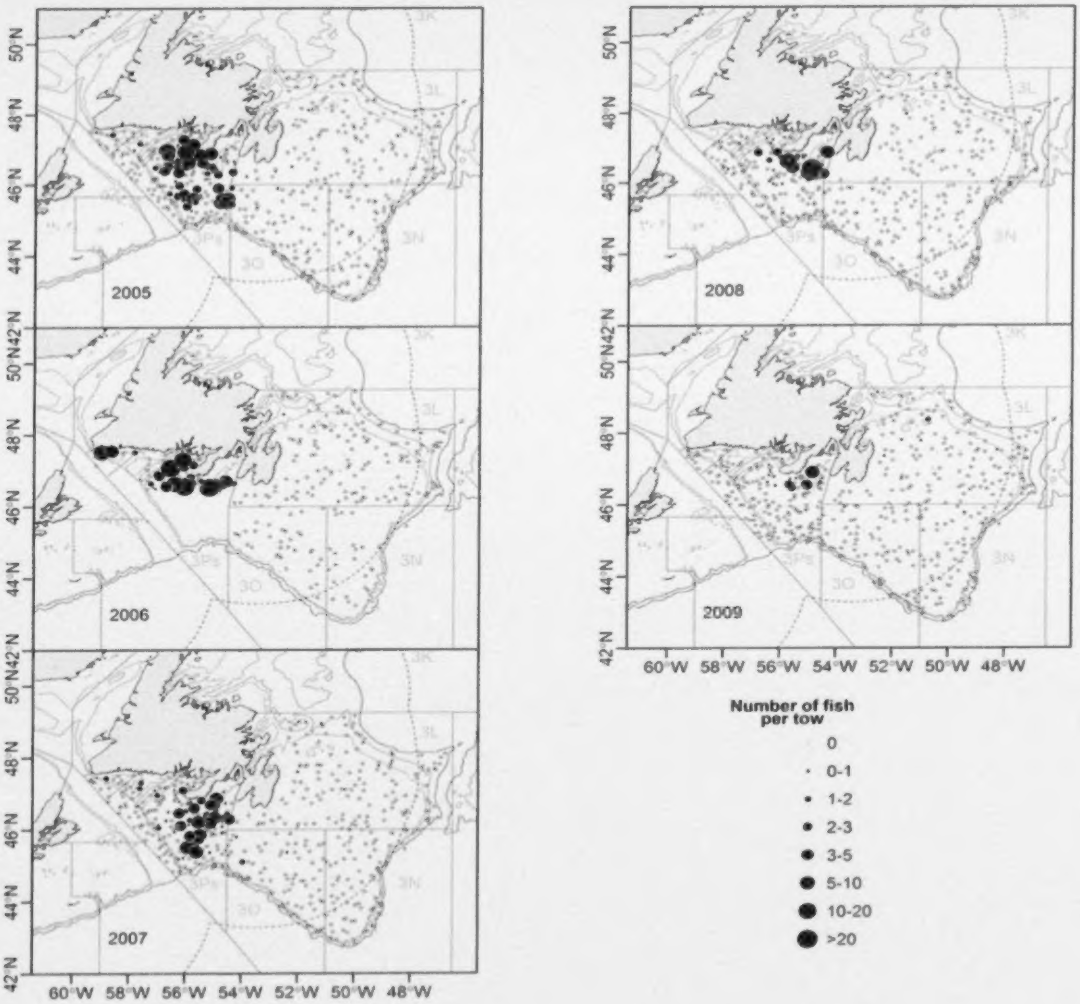
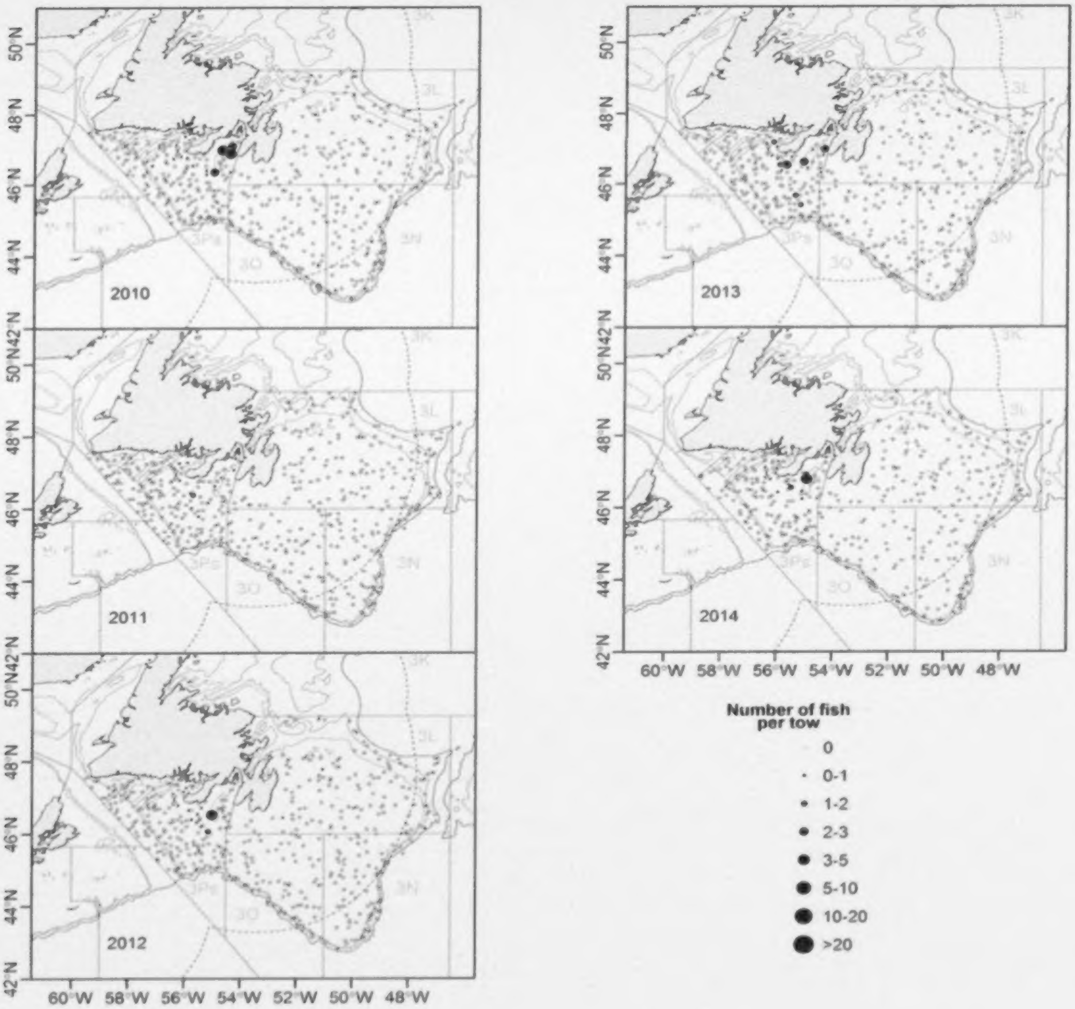

2005
2006
2007
2008
2009
3K
3L
3N
3O
3Ps
50°N
48°N
46°N
44°N
42°N
60°W
58°W
56°W
54°W
52°W
50°W
48°W
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 13. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-NL spring Campelen research surveys, 2005-09.



2010
2011
2012
2013
2014
3K
3L
3Ps
3O
3N
50°N
48°N
46°N
44°N
42°N
60°W
58°W
56°W
54°W
52°W
50°W
48°W
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 14. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-NL spring Campelen research surveys, 2010-14.

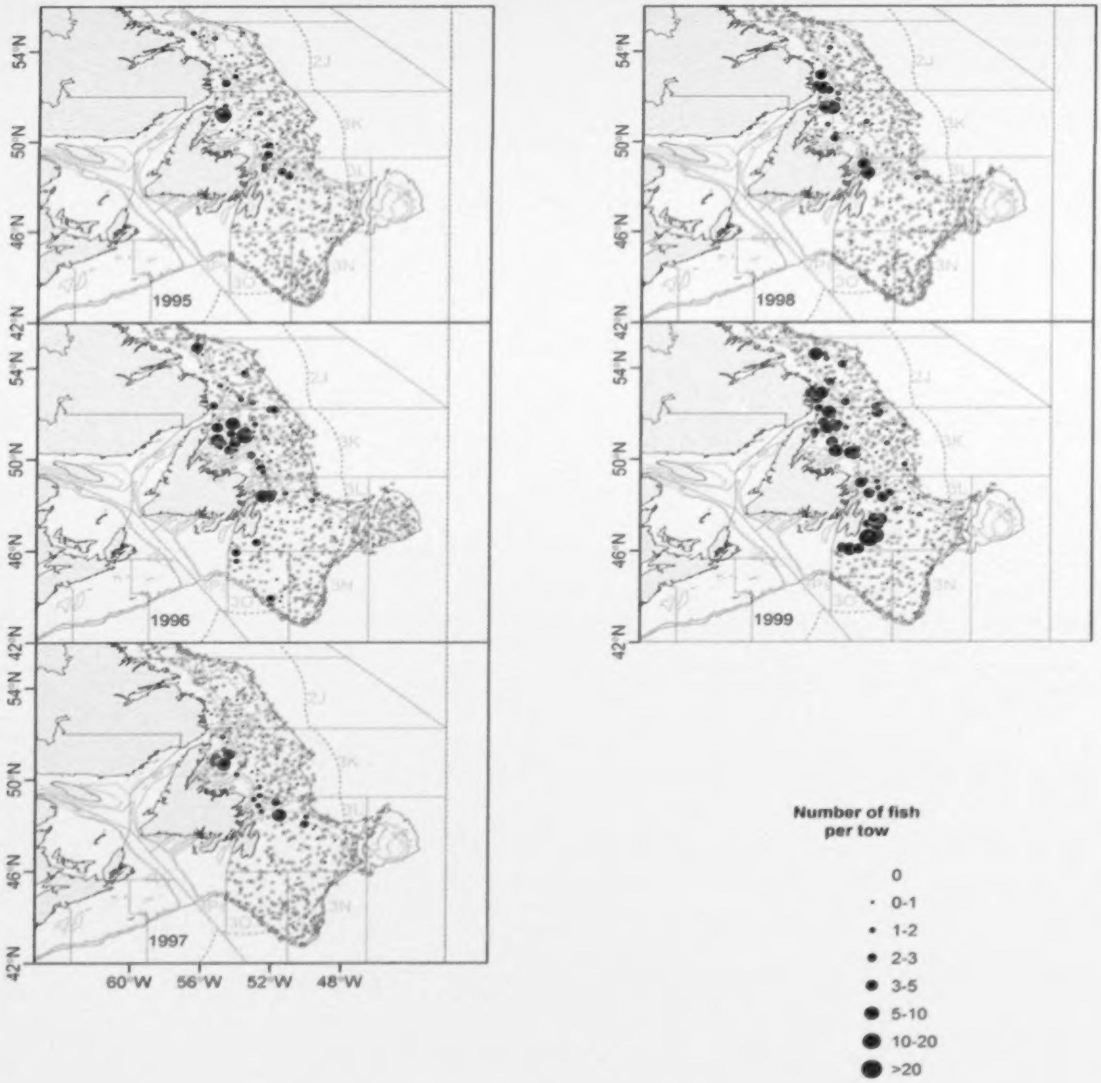

54°N
50°N
46°N
42°N
60°W
56°W
52°W
48°W
2J
3K
3L
3N
3O
3Ps
1995
1996
1997
1998
1999
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 15. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-NL fall Campelen research surveys, 1995-99.

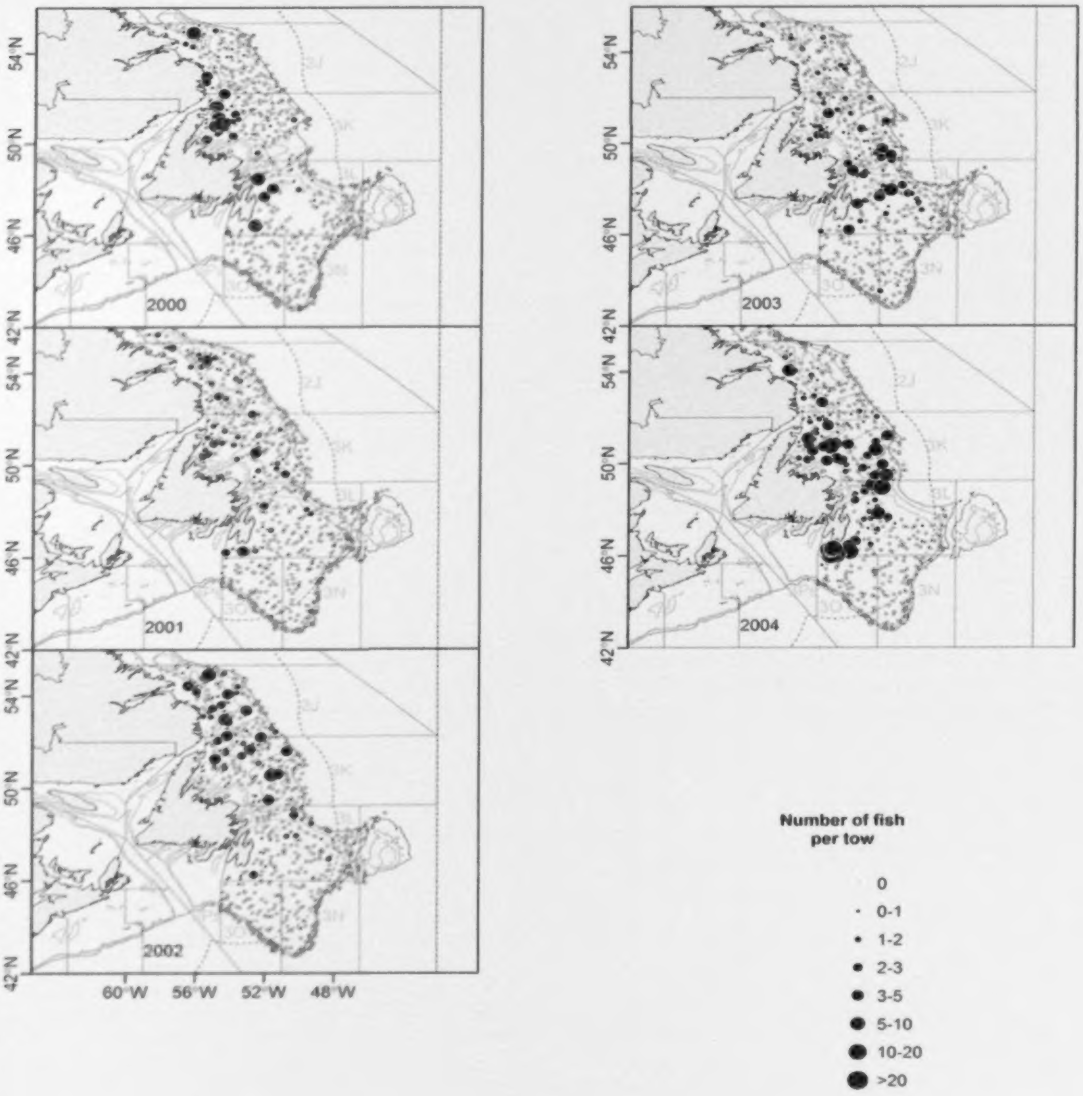

2000
2001
2002
2003
2004
54°N
50°N
46°N
42°N
60°W
56°W
52°W
48°W
2J
3K
3L
3N
3O
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 16. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-NL fall Campelen research surveys, 2000-04.

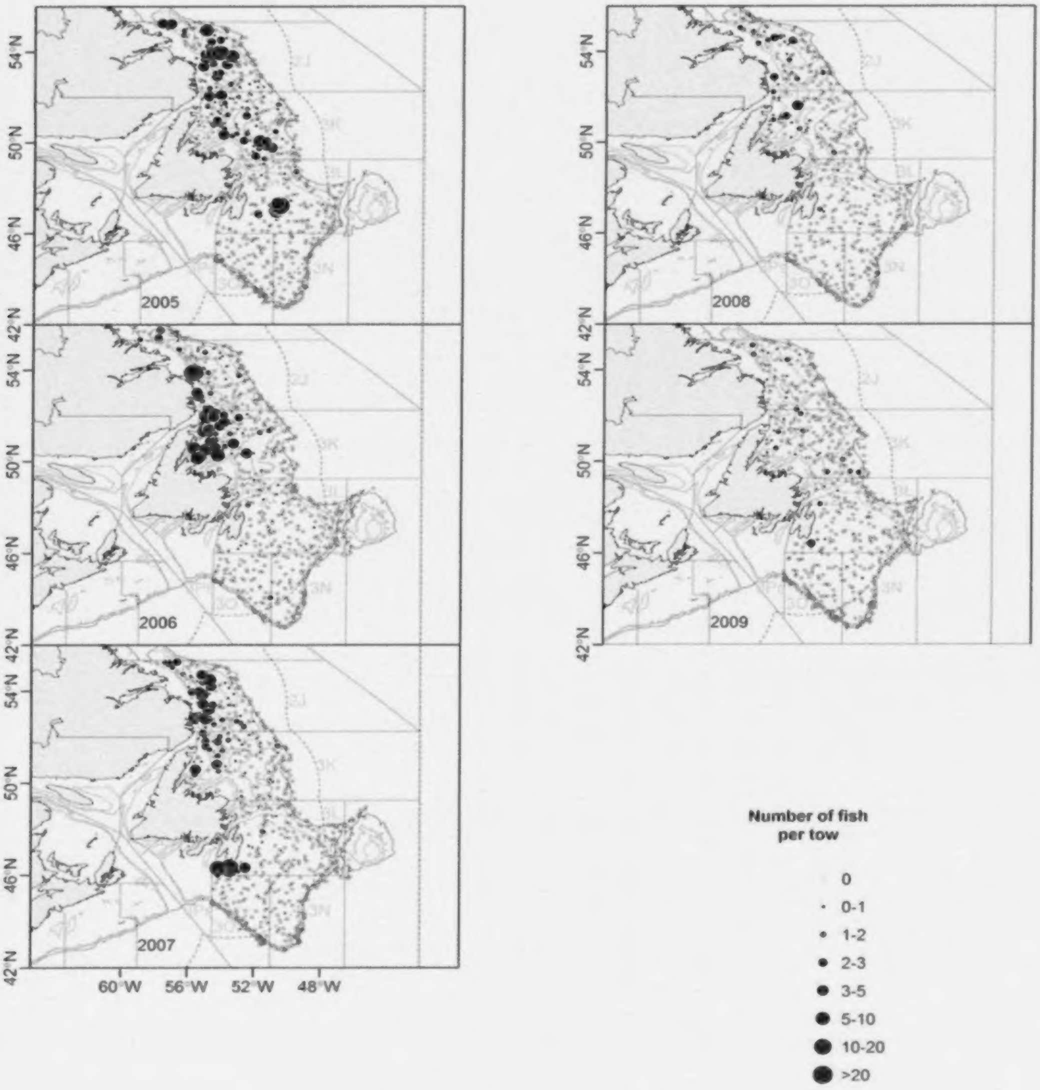

54°N
50°N
46°N
42°N
2J
3K
3L
3N
3O
3Ps
2005
2006
2007
2008
2009
60°W
56°W
52°W
48°W
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 17. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-NL fall Campelen research surveys, 2005-09.

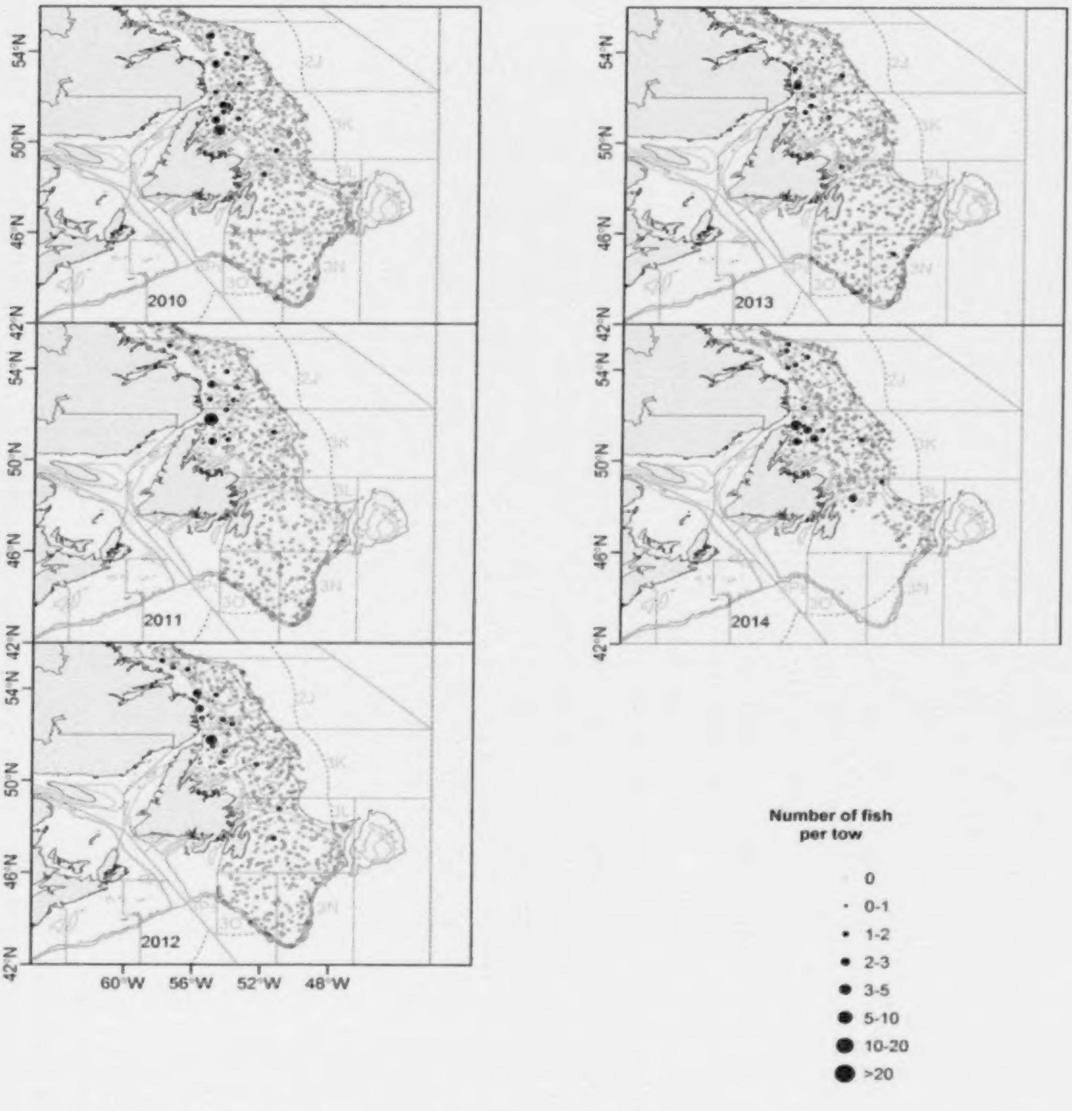

2010
2011
2012
2013
2014
2J
3K
3L
3N
3O
3Ps
54°N
50°N
46°N
42°N
60°W
56°W
52°W
48°W
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 18. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-NL fall Campelen research surveys, 2010-14.

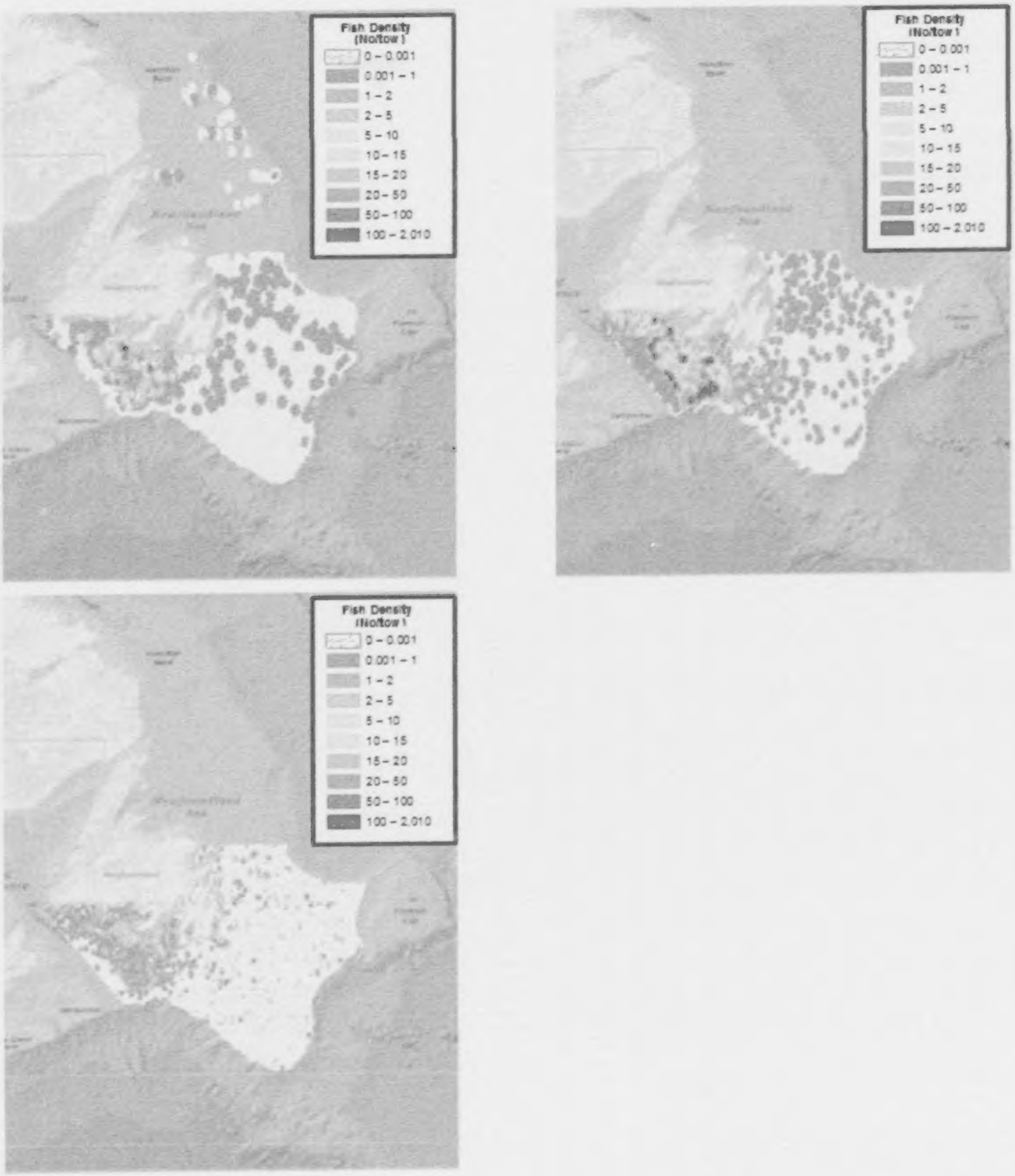

Fish Density
(No/tow)
0 – 0.001
0.001 – 1
1 – 2
2 – 5
5 – 10
10 – 15
15 – 20
20 – 50
50 – 100
100 – 2,010
Fish Density
(No/tow)
0 – 0.001
0.001 – 1
1 – 2
2 – 5
5 – 10
10 – 15
15 – 20
20 – 50
50 – 100
100 – 2,010
Fish Density
(No/tow)
0 – 0.001
0.001 – 1
1 – 2
2 – 5
5 – 10
10 – 15
15 – 20
20 – 50
50 – 100
100 – 2,010

Figure 19. Kernel surface density plots for Common Lumpfish from DFO-NL spring surveys in: 1972-82 (Yankee trawl; top left panel), 1983-95 (Engel trawl; top right panel), and 1996-2014 (Campelen trawl; bottom left panel).

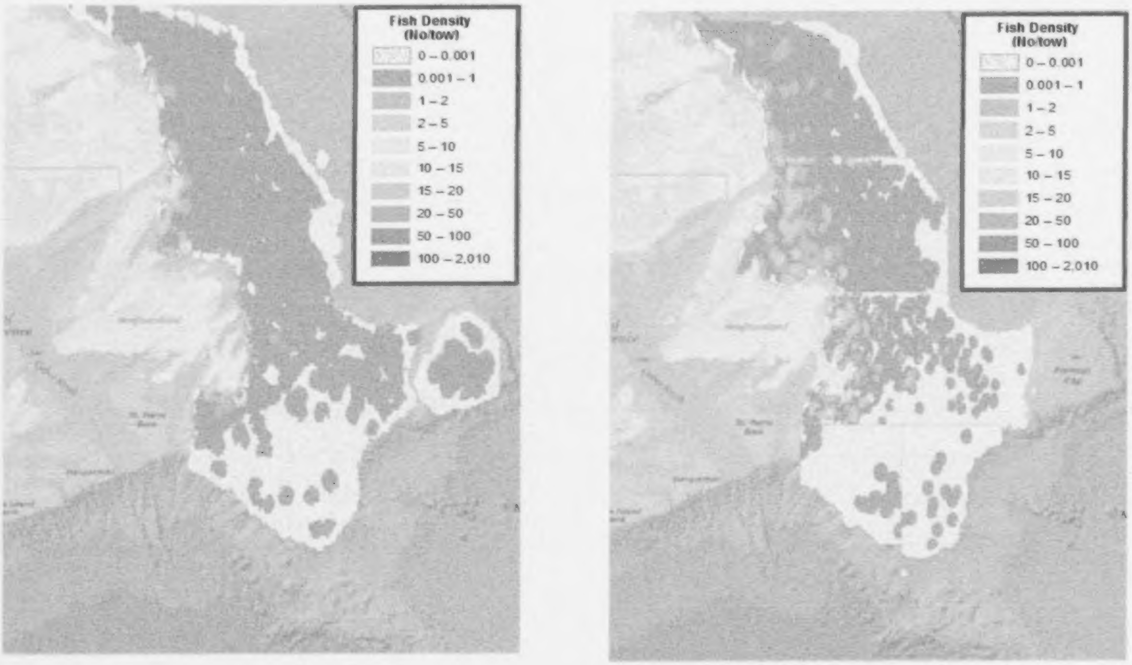

Fish Density (No/tow)
0 – 0.001
0.001 – 1
1 – 2
2 – 5
5 – 10
10 – 15
15 – 20
20 – 50
50 – 100
100 – 2,010
Fish Density (No/tow)
0 – 0.001
0.001 – 1
1 – 2
2 – 5
5 – 10
10 – 15
15 – 20
20 – 50
50 – 100
100 – 2,010

Figure 20. Kernel surface density plots for Common Lumpfish from DFO-NL fall surveys in: 1983-94 (Engel trawl; left panel), and 1995-2014 (Campelen trawl; right panel).

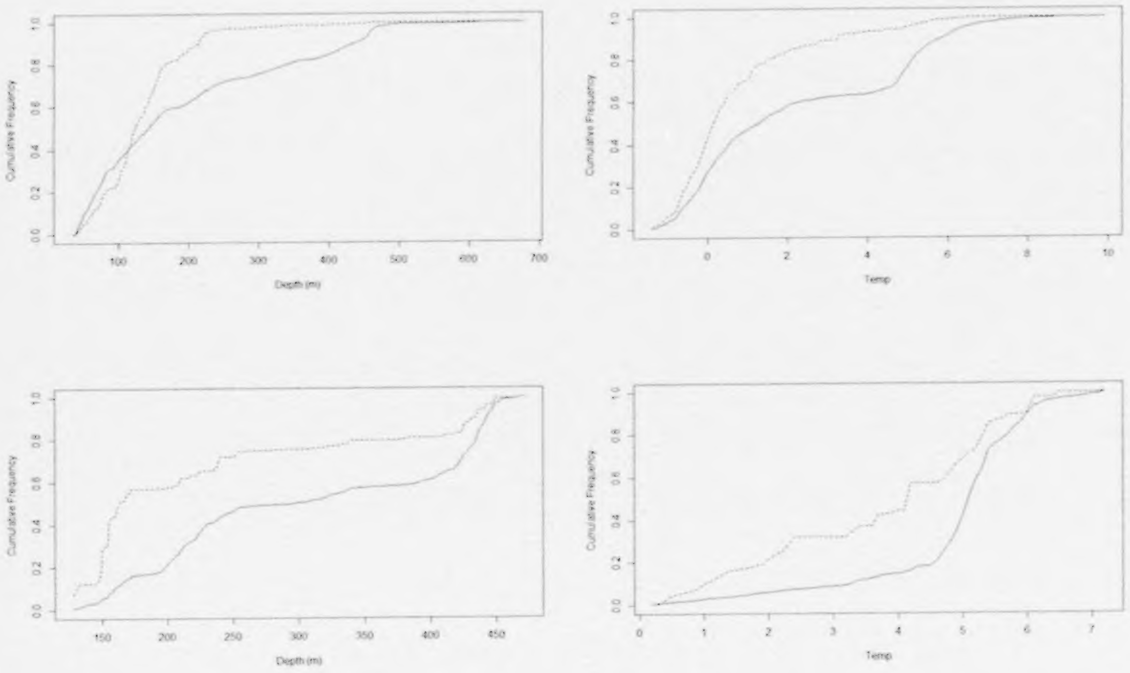


Figure 21. Cumulative frequency distributions of Common Lumpfish depth and bottom temperature associations in Subdiv. 3Ps (top panels) and Subdiv. 3Pn (bottom panels) from DFO-NL spring Campelen surveys, 1996-2014. Dotted line represents catch-weighted distribution.

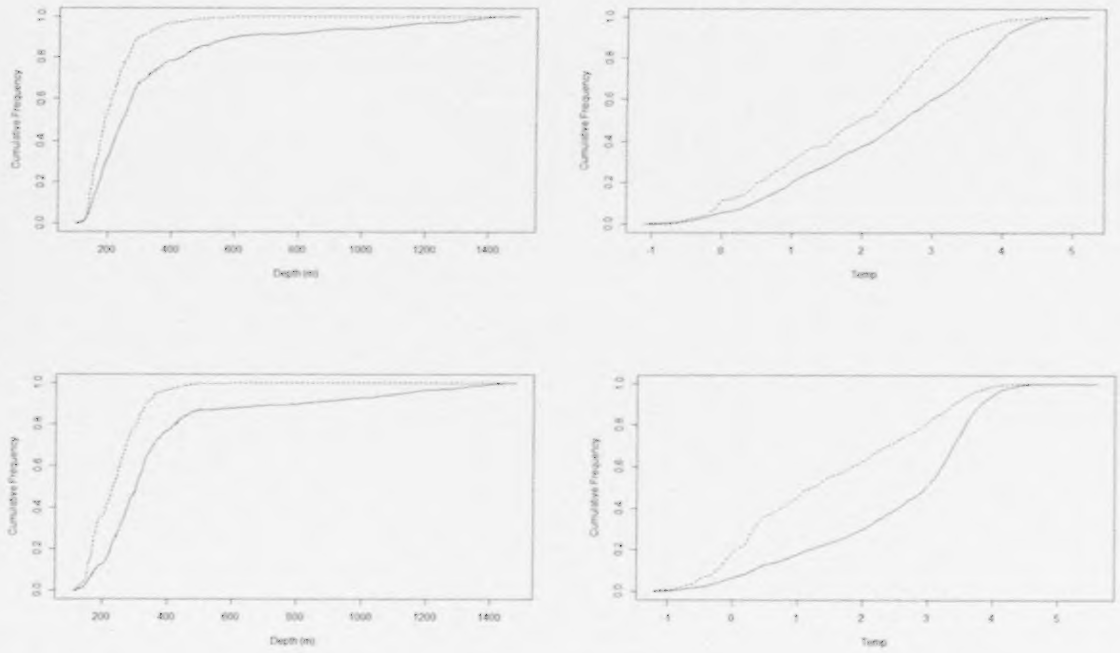


Figure 22. Cumulative frequency distributions of Common Lumpfish depth and bottom temperature associations in Div. 2J (top panels) and Div. 3K (bottom panels) from DFO-NL fall Campelen surveys, 1995-2013. Dotted line represents catch-weighted distribution.

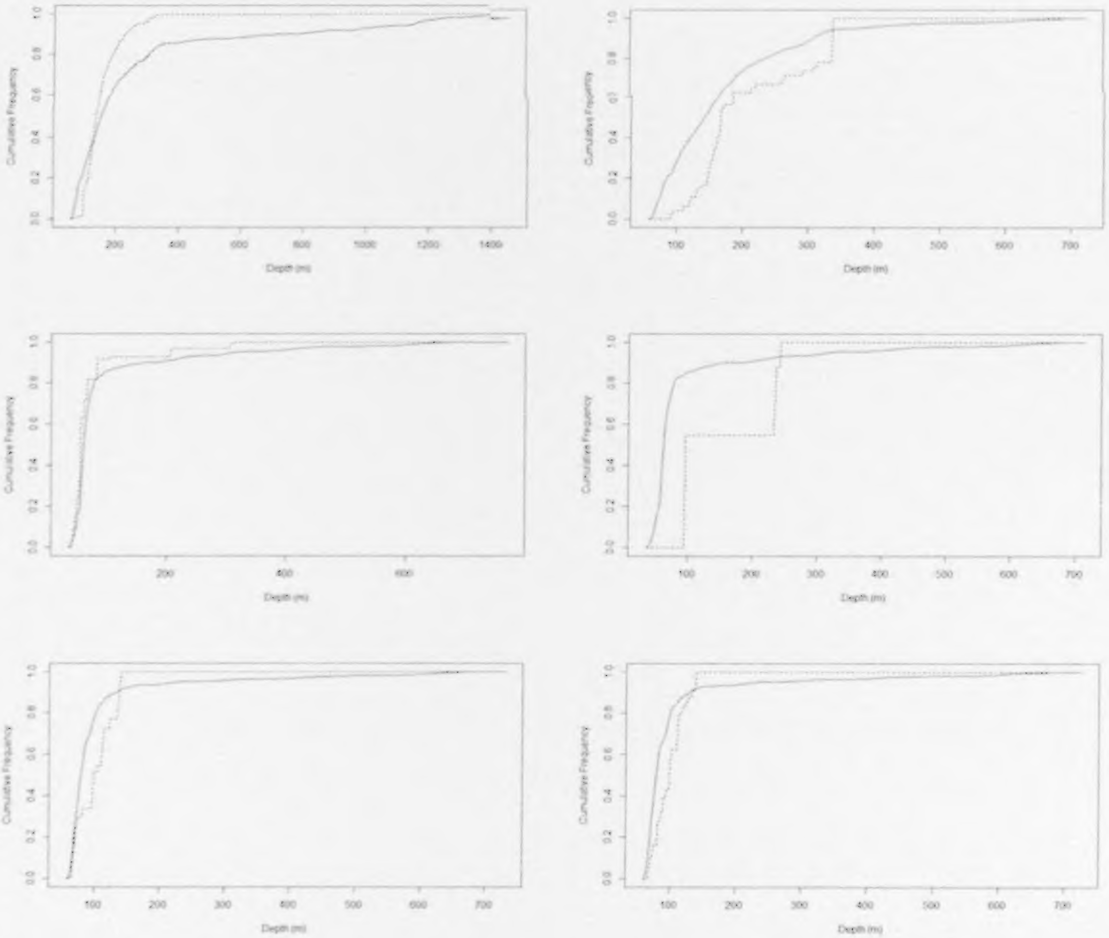


Figure 23. Cumulative frequency distributions of Common Lumpfish depth associations in Divs. 3LNO from DFO-NL Campelen surveys in fall 1995-2013 (left column) and spring 1996-2014 (right column): Div. 3L (top panels); Div. 3N (middle panels); and Div. 3O (bottom panels). Dotted line represents catch-weighted distribution.

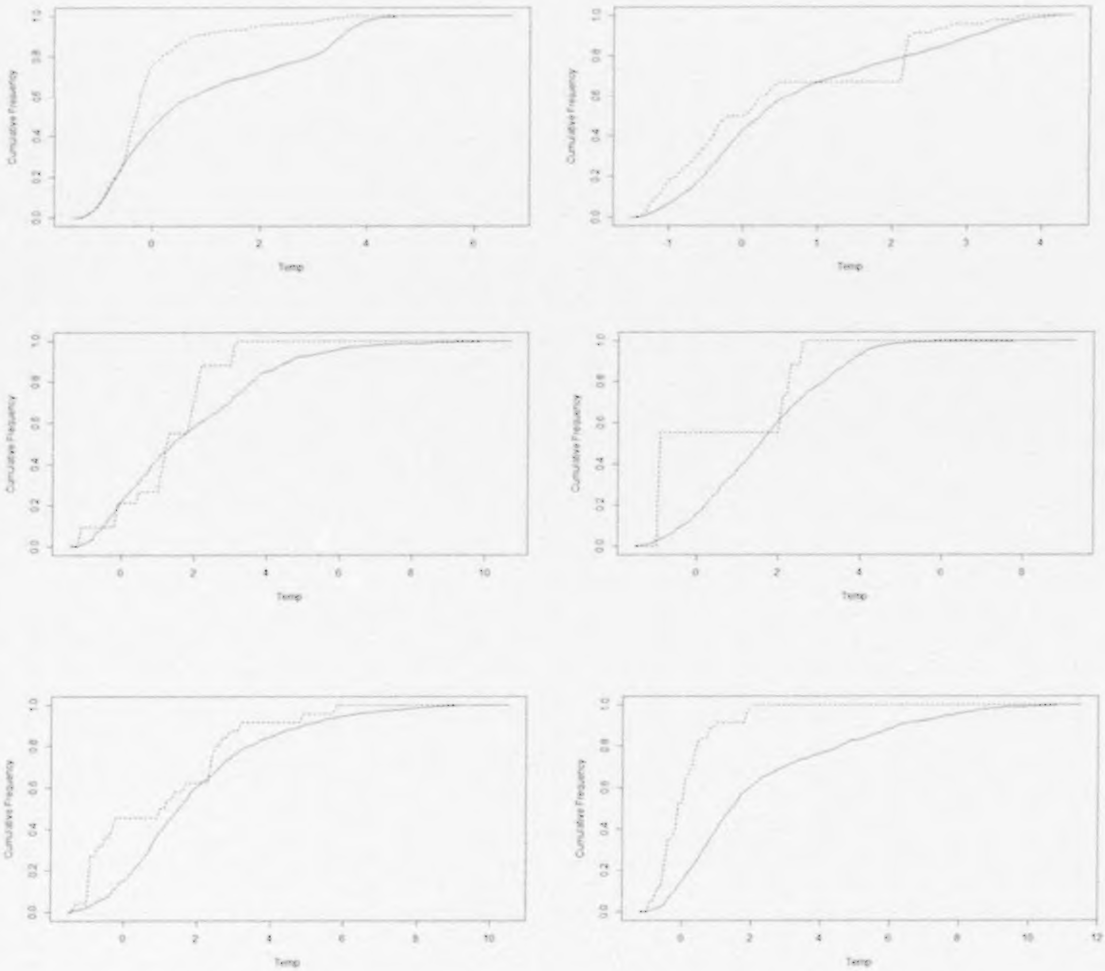


Figure 24. Cumulative frequency distributions of Common Lumpfish bottom temperature associations in Divs. 3LNO from DFO-NL Campelen surveys in fall 1995-2013 (left column) and spring 1996-2014 (right column): Div. 3L (top panels); Div. 3N (middle panels); and Div. 3O (bottom panels). Dotted line represents catch-weighted distribution.

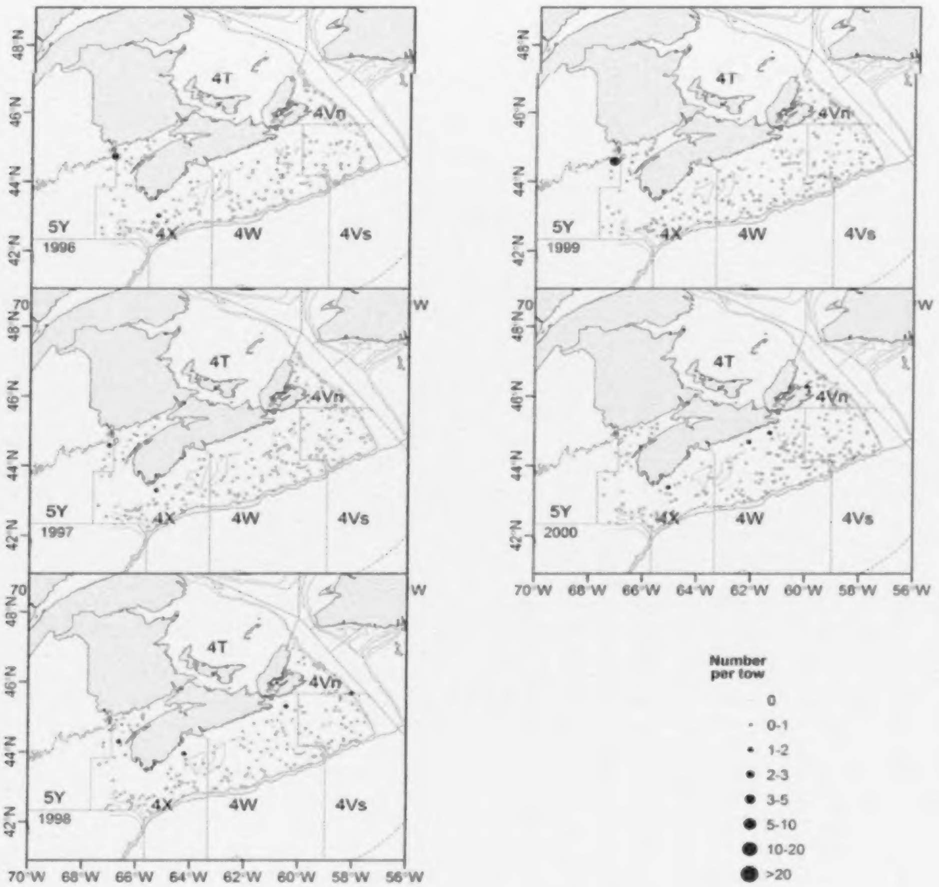

48°N
46°N
44°N
42°N
4T
4Vn
5Y
4X
4W
4Vs
1996
1997
1998
1999
2000
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
Number per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 25. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-MAR summer research surveys in Divs. 4VWX, 1996-2000.

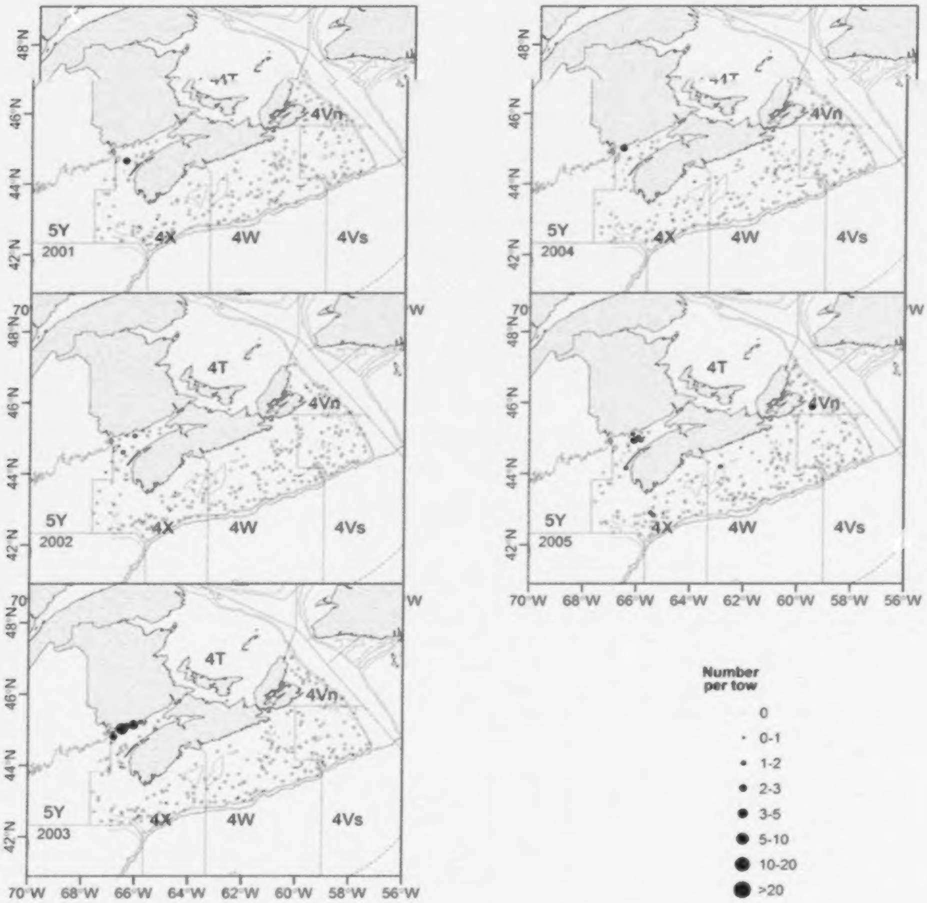

48°N
46°N
44°N
42°N
4T
4Vn
5Y
4X
4W
4Vs
2001
2002
2003
2004
2005
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
Number per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 26. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-MAR summer research surveys in Divs. 4VWX, 2001-05.

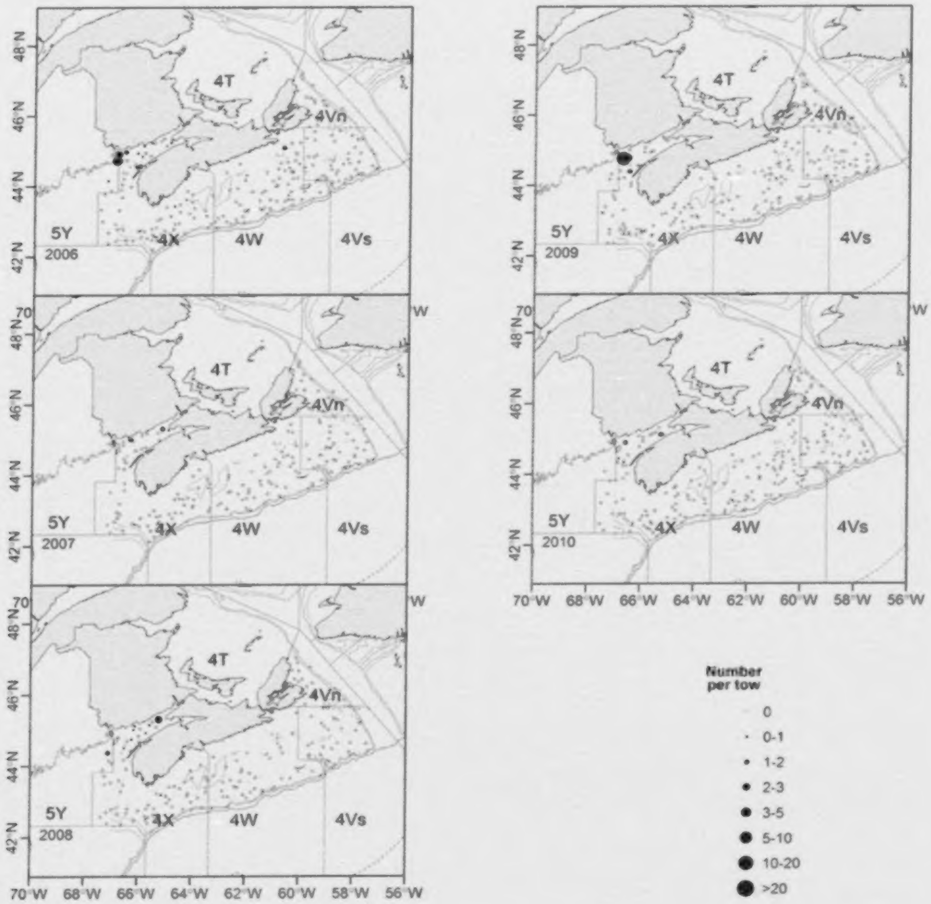

4T
4Vn
5Y
4X
4W
4Vs
2006
2009
2007
2010
2008
48°N
46°N
44°N
42°N
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
Number per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 27. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-MAR summer research surveys in Divs. 4VWX, 2006-10.

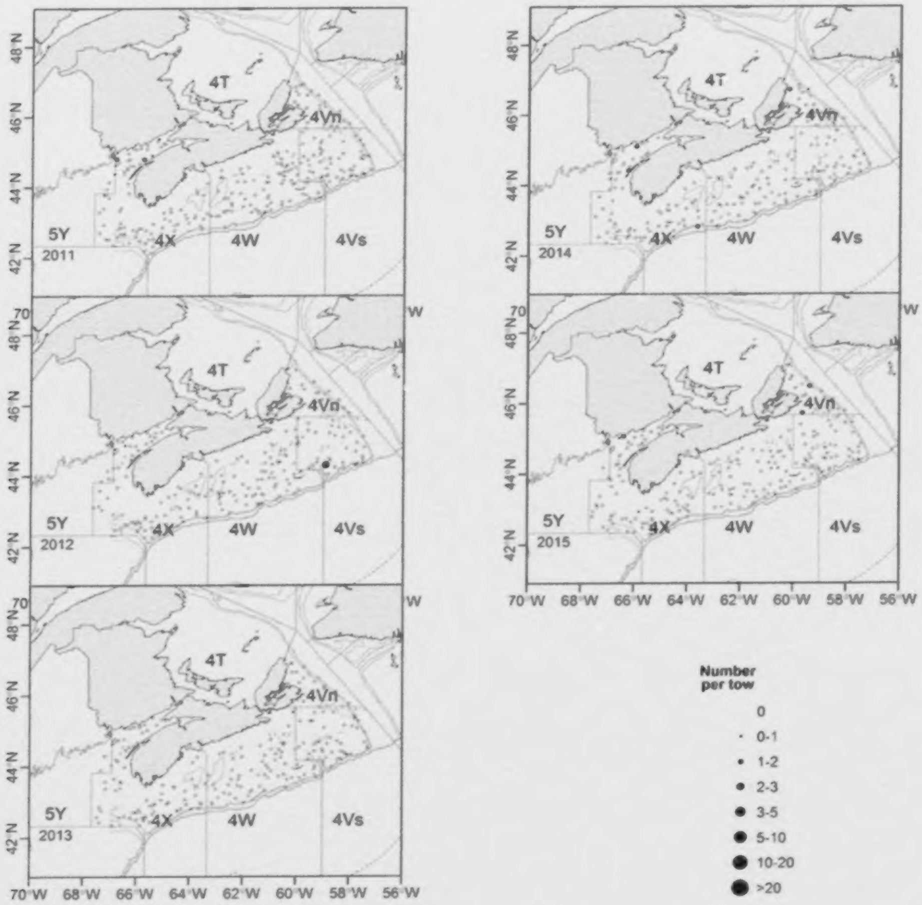

4T
4Vn
5Y
4X
4W
4Vs
2011
2012
2013
2014
2015
42°N
44°N
46°N
48°N
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
Number per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 28. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-MAR summer research surveys in Divs. 4VWX, 2011-15.

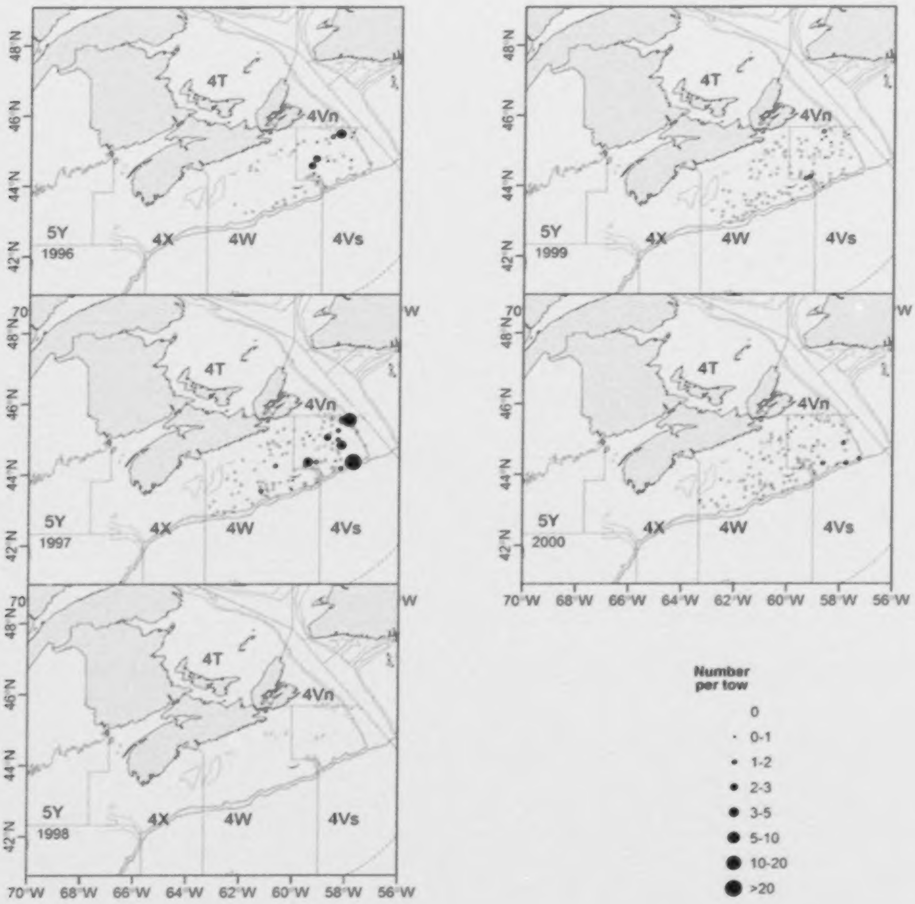

48°N
46°N
44°N
42°N
4T
4Vn
5Y
4X
4W
4Vs
1996
1997
1998
1999
2000
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
Number per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 29. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-MAR March 4VsW research surveys, 1996-2000.

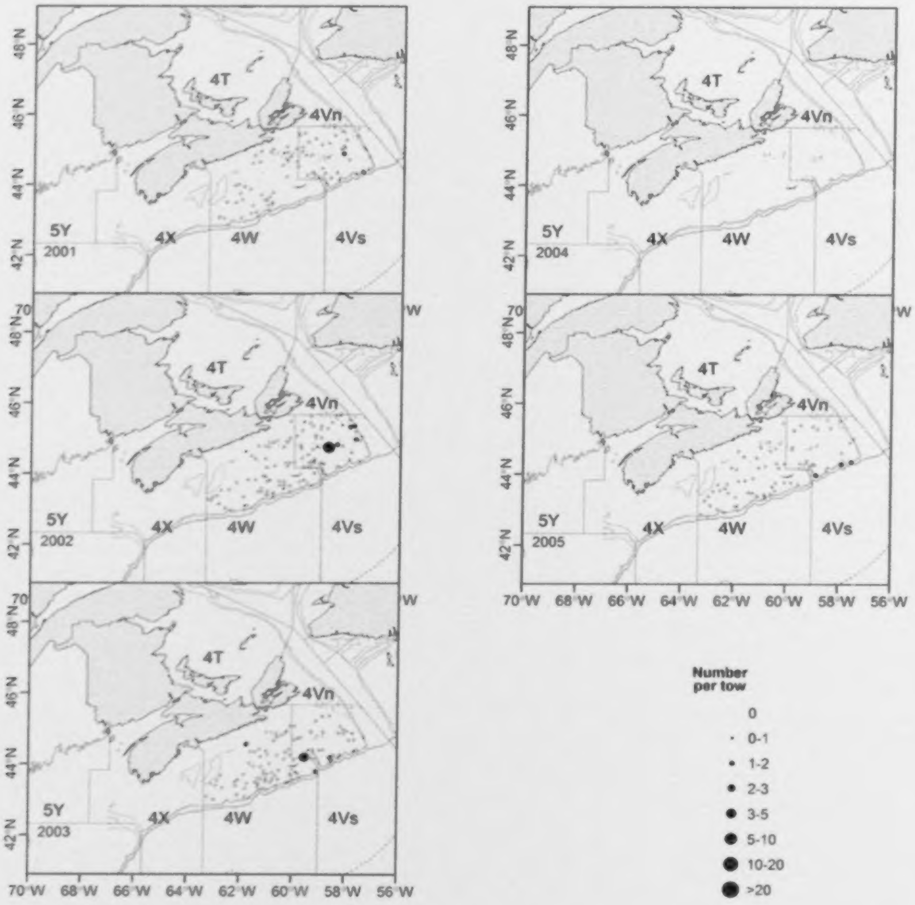

4T
4Vn
5Y
4X
4W
4Vs
2001
2002
2003
2004
2005
48°N
46°N
44°N
42°N
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
Number per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 30. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-MAR March 4VsW research surveys, 2001-05.

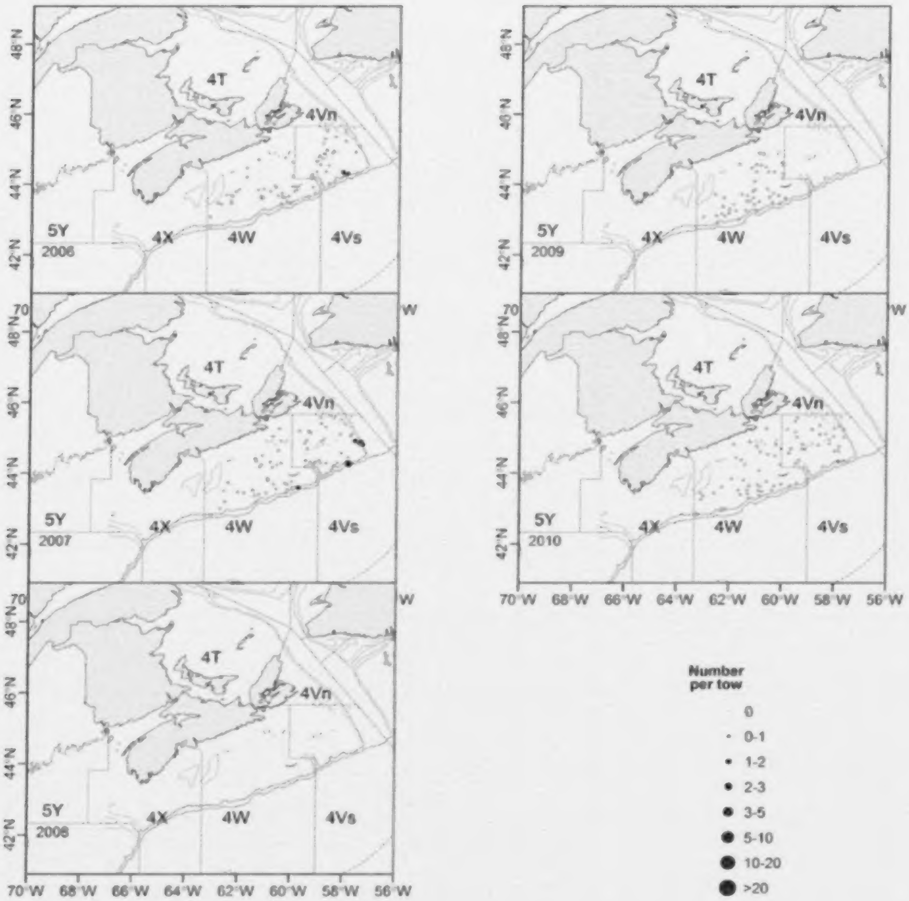

4T
4Vn
5Y
4X
4W
4Vs
2006
2007
2008
2009
2010
48°N
46°N
44°N
42°N
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
Number per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 31. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-MAR March 4VsW research surveys, 2006-10.

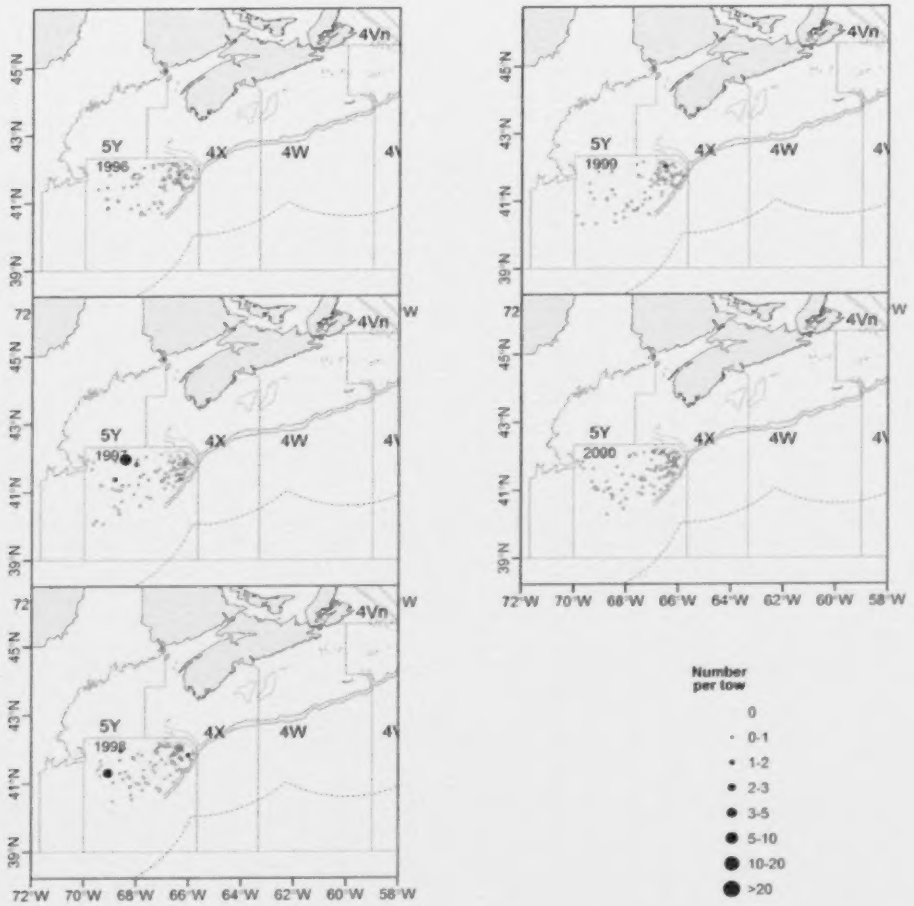

4Vn
5Y
4X
4W
1996
1997
1998
1999
2000
45°N
43°N
41°N
39°N
72°W
70°W
68°W
66°W
64°W
62°W
60°W
58°W
Number per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 32. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-MAR Georges Bank winter research surveys, 1996-2000.

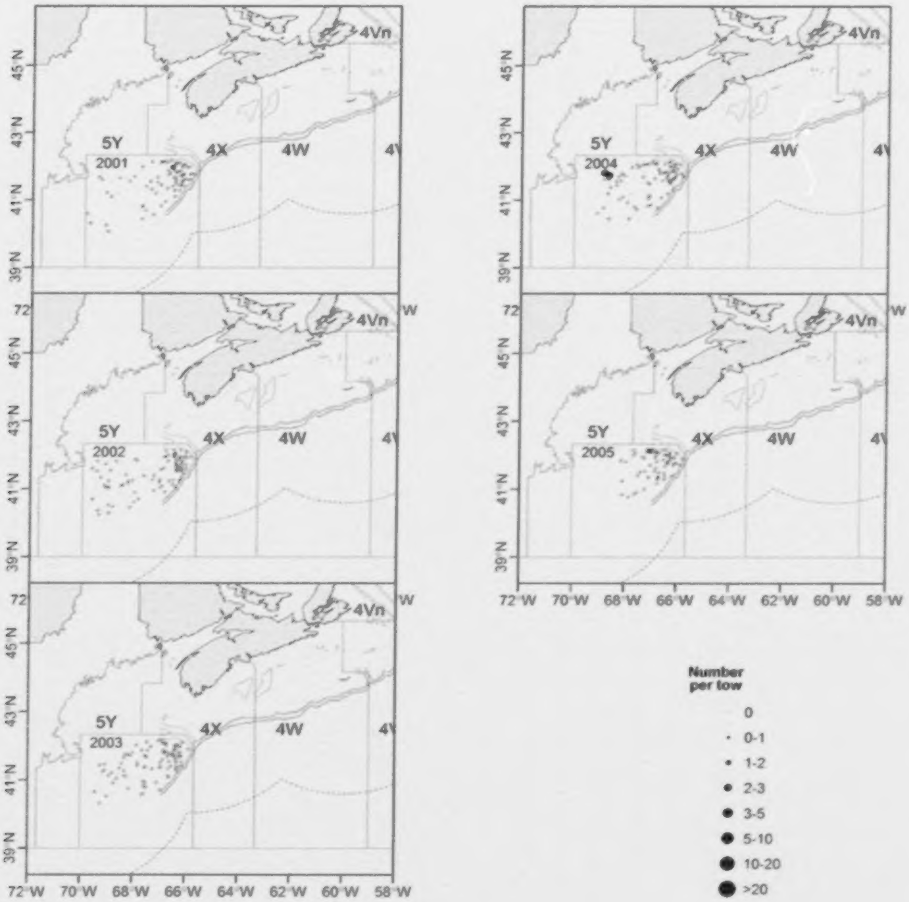

5Y
4X
4W
4Vn
2001
2002
2003
2004
2005
45°N
43°N
41°N
39°N
72°W
70°W
68°W
66°W
64°W
62°W
60°W
58°W
Number per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 33. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-MAR Georges Bank winter research surveys, 2001-05.

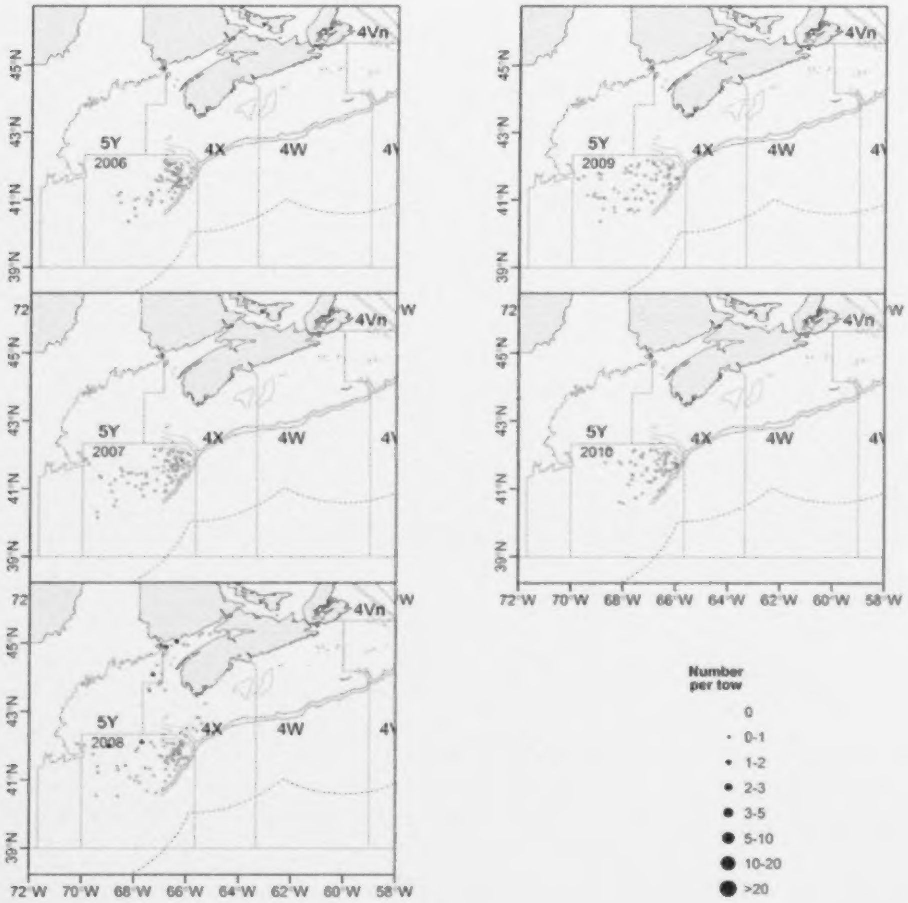

4Vn
5Y
4X
4W
2006
2007
2008
2009
2010
45°N
43°N
41°N
39°N
72°W
70°W
68°W
66°W
64°W
62°W
60°W
58°W
Number per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 34. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-MAR Georges Bank winter research surveys, 2006-10.

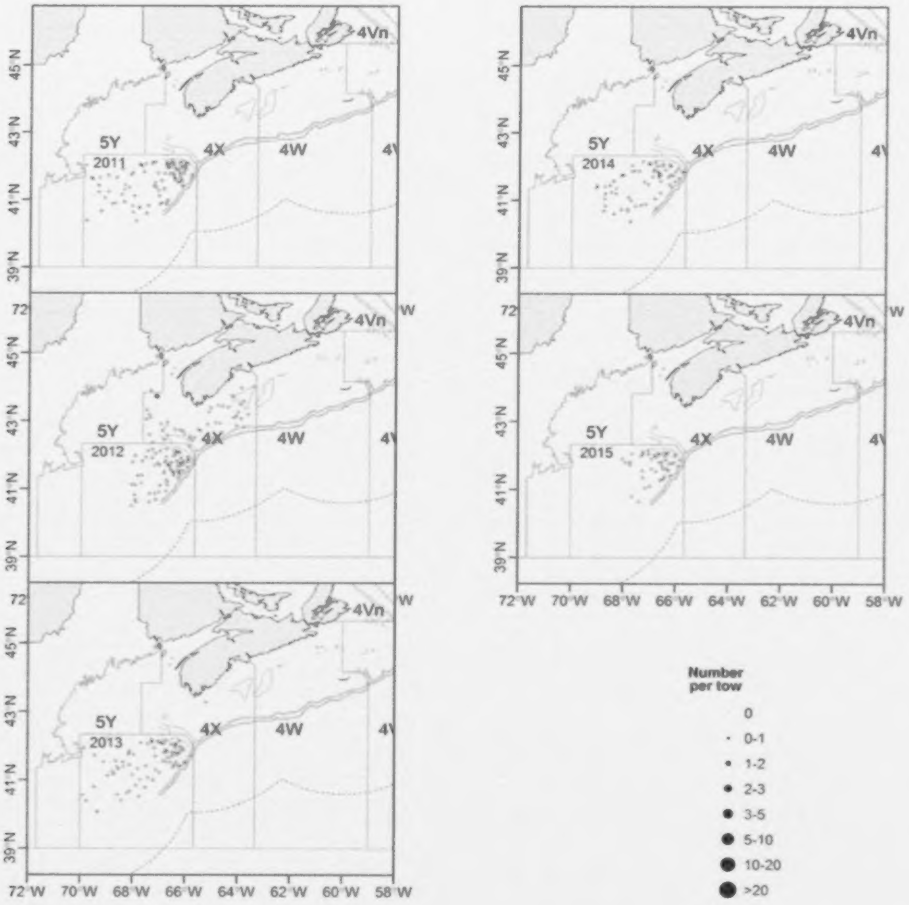

4Vn
5Y
2011
2012
2013
2014
2015
4X
4W
45°N
43°N
41°N
39°N
72°W
70°W
68°W
66°W
64°W
62°W
60°W
58°W
Number per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 35. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-MAR Georges Bank winter research surveys, 2011-15.

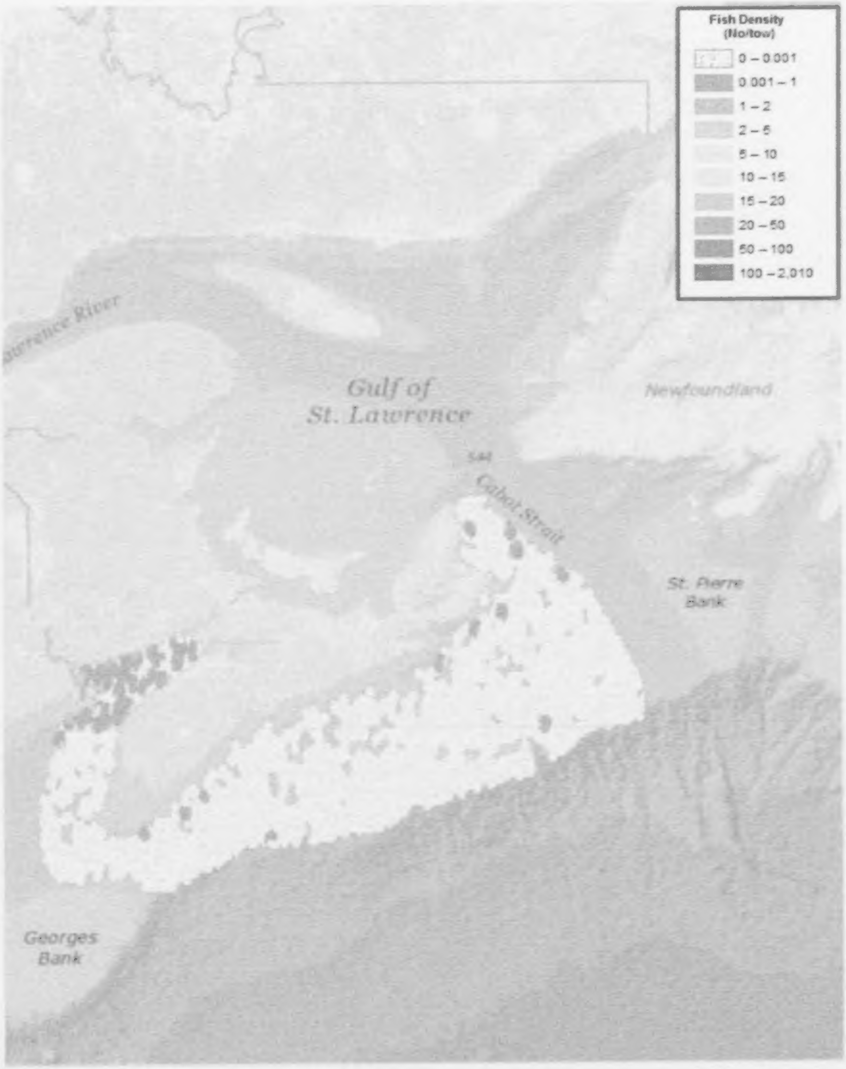

Fish Density
(No/tow)
0 – 0.001
0.001 – 1
1 – 2
2 – 5
5 – 10
10 – 15
15 – 20
20 – 50
50 – 100
100 – 2,010
Lawrence River
Gulf of
St. Lawrence
Newfoundland
Cabot Strait
St. Pierre
Bank
Georges
Bank

Figure 36. Kernel density plot of the DFO-MAR summer research surveys (Divs. 4VWX), 2006-15.

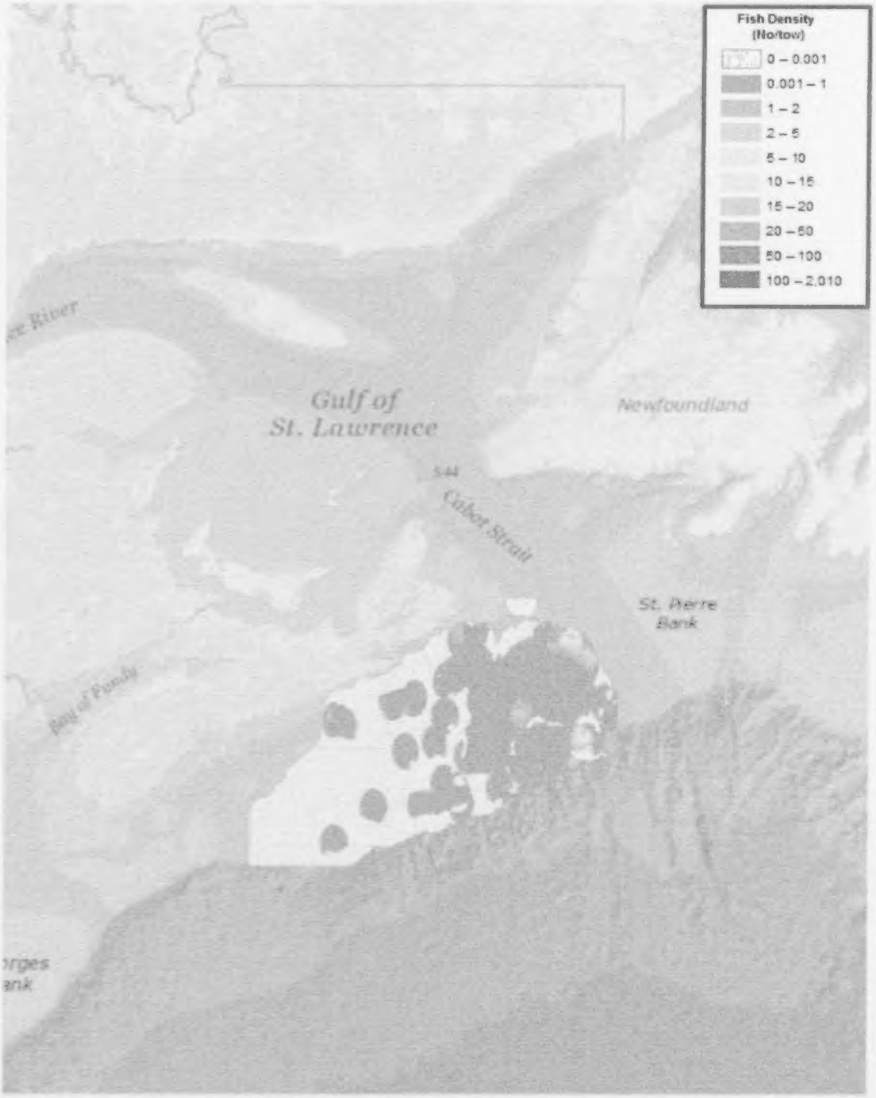

Fish Density (No/tow)
0 – 0.001
0.001 – 1
1 – 2
2 – 5
5 – 10
10 – 15
15 – 20
20 – 50
50 – 100
100 – 2,010
Gulf of St. Lawrence
Newfoundland
Cabot Strait
St. Pierre Bank
Bay of Fundy

Figure 37. Kernel density plot of the DFO-MAR Div. 4VsW March research survey, 1995-2010.

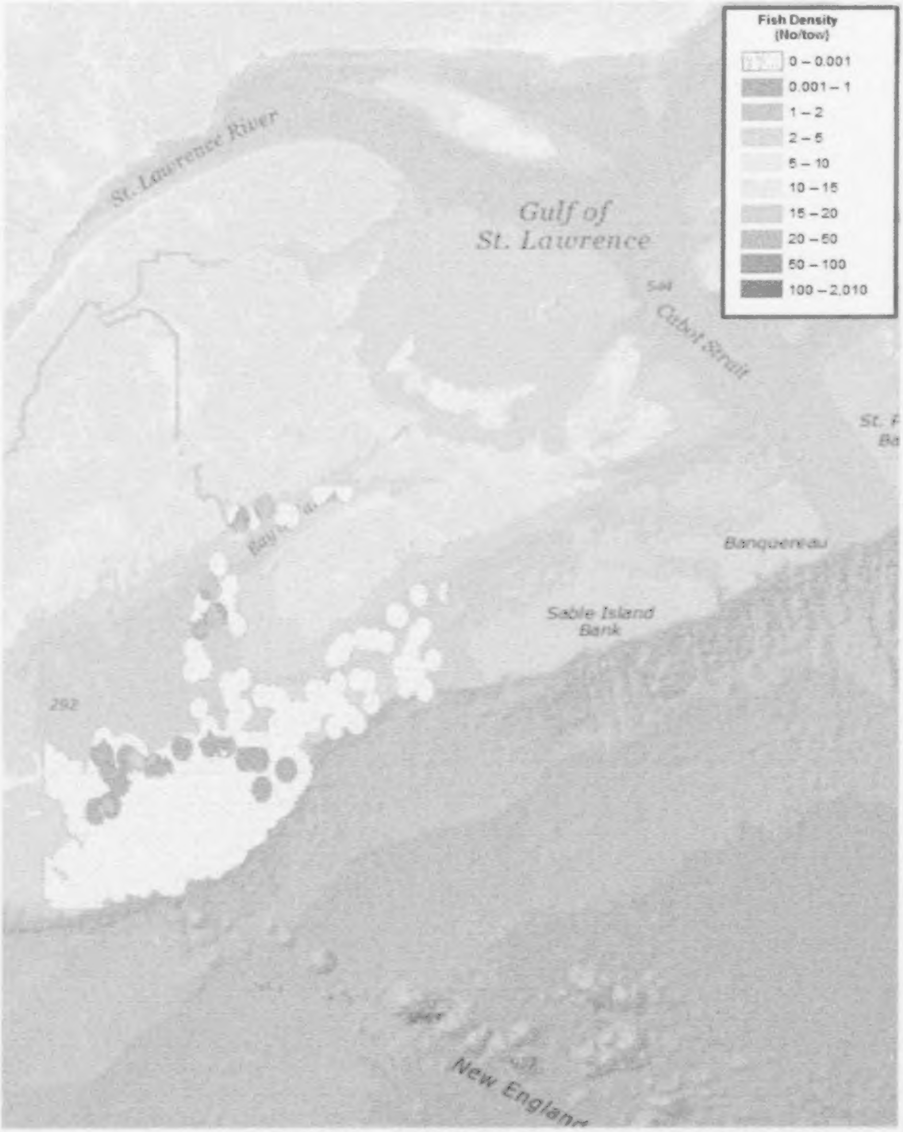

Fish Density
(No/tow)
0 – 0.001
0.001 – 1
1 – 2
2 – 5
5 – 10
10 – 15
15 – 20
20 – 50
50 – 100
100 – 2,010
St. Lawrence River
Gulf of
St. Lawrence
Cabot Strait
Banquereau
Sable Island
Bank
292
New England

Figure 38. Kernel density plot of the DFO-MAR Georges Bank winter research survey, 1996-2015.

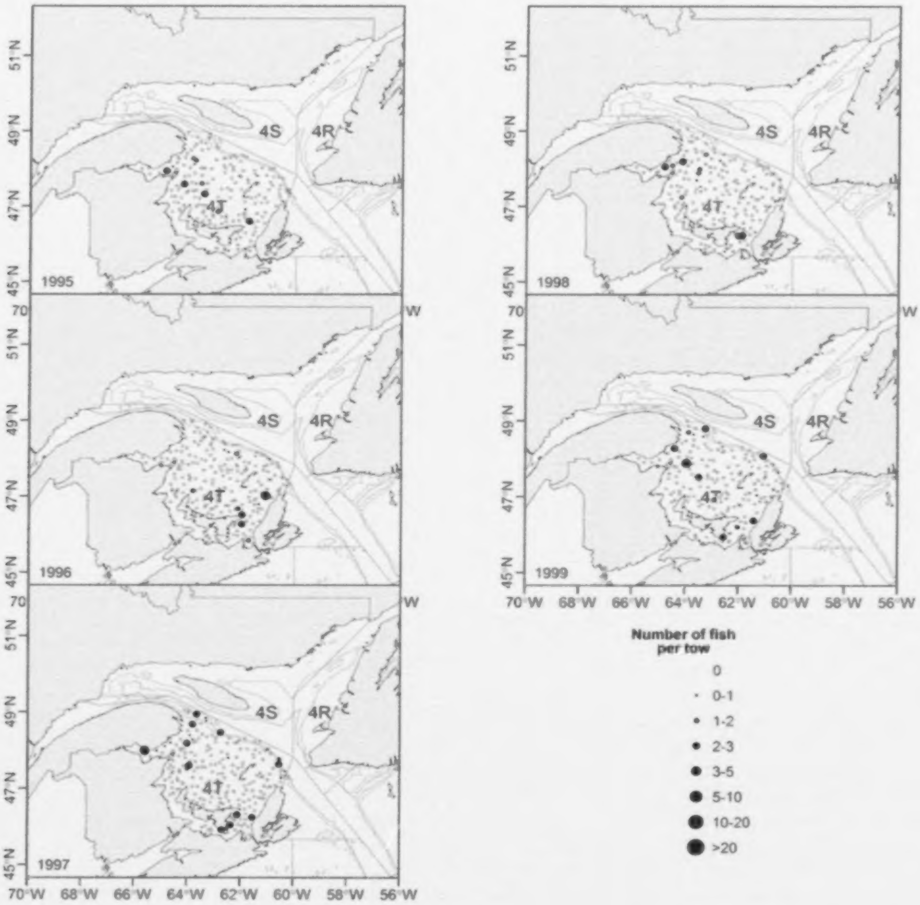

4S
4R
4T
1995
1996
1997
1998
1999
45°N
47°N
49°N
51°N
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 39. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-Gulf research survey of Div. 4T, 1995-99.

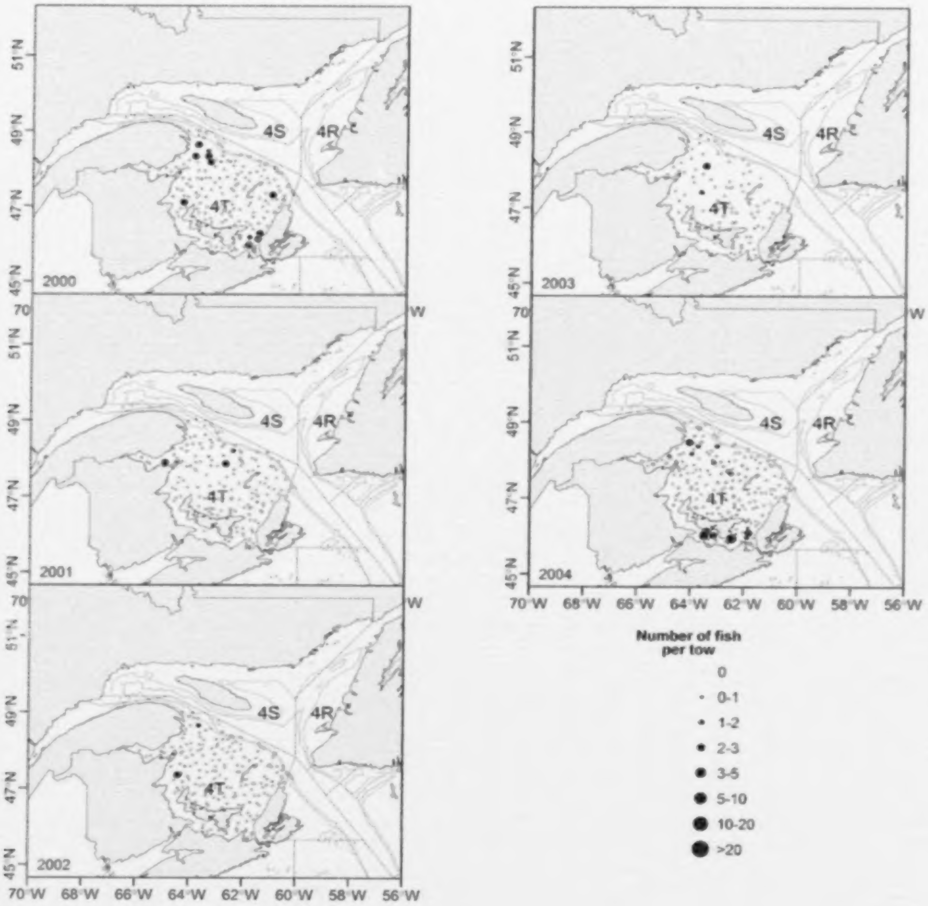

2000
2001
2002
2003
2004
4S
4R
4T
51°N
49°N
47°N
45°N
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 40. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-Gulf research survey of Div. 4T, 2000-04.

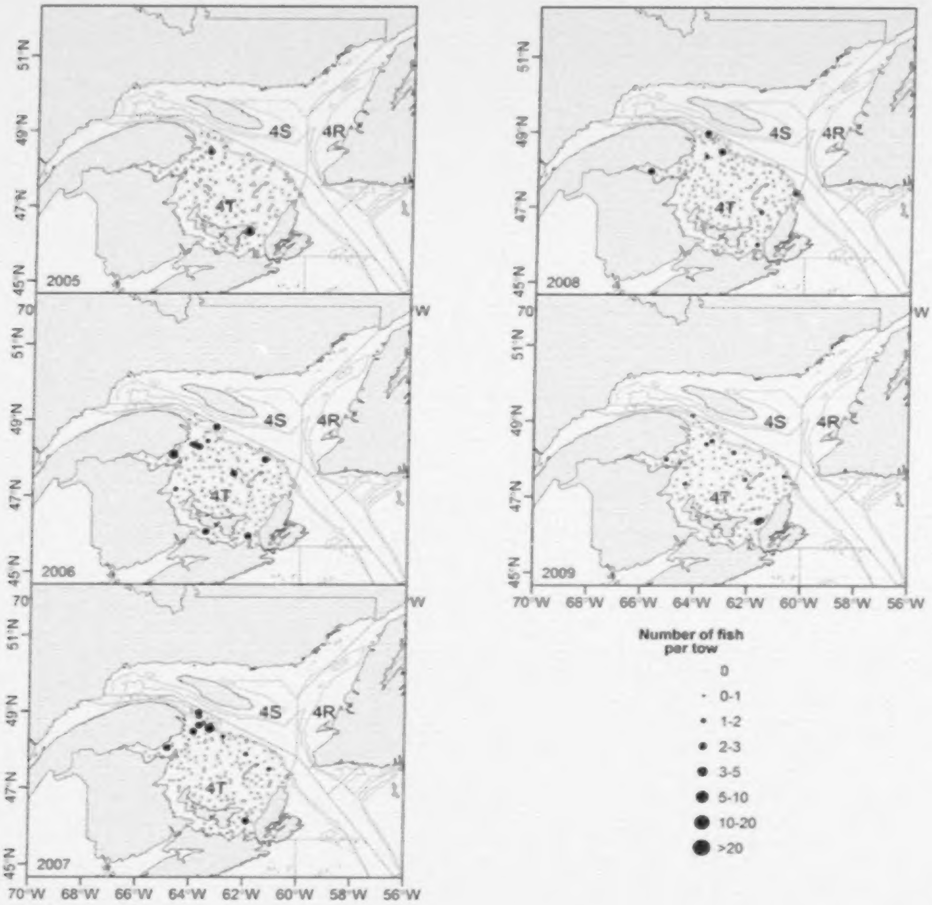

51°N
49°N
47°N
45°N
4S
4R
4T
2005
2006
2007
2008
2009
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 41. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-Gulf research survey of Div. 4T, 2005-09.

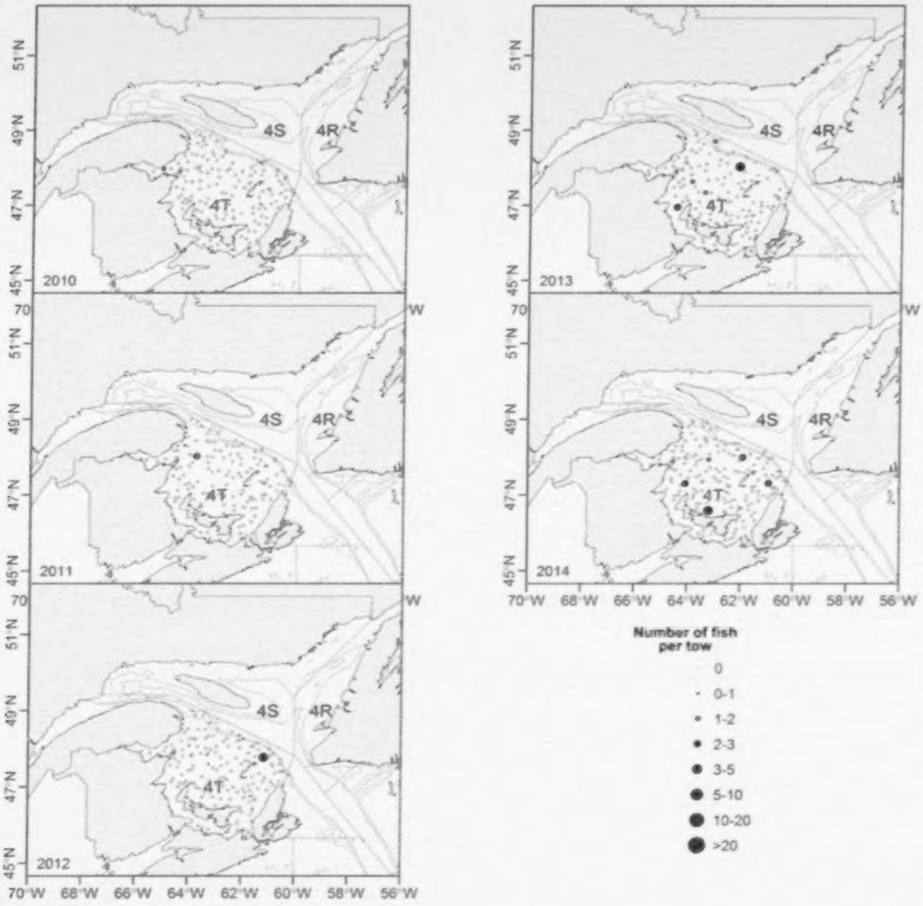

2010
2011
2012
2013
2014
4S
4R
4T
45°N
47°N
49°N
51°N
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 42. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-Gulf research survey of Div. 4T, 2010-14.

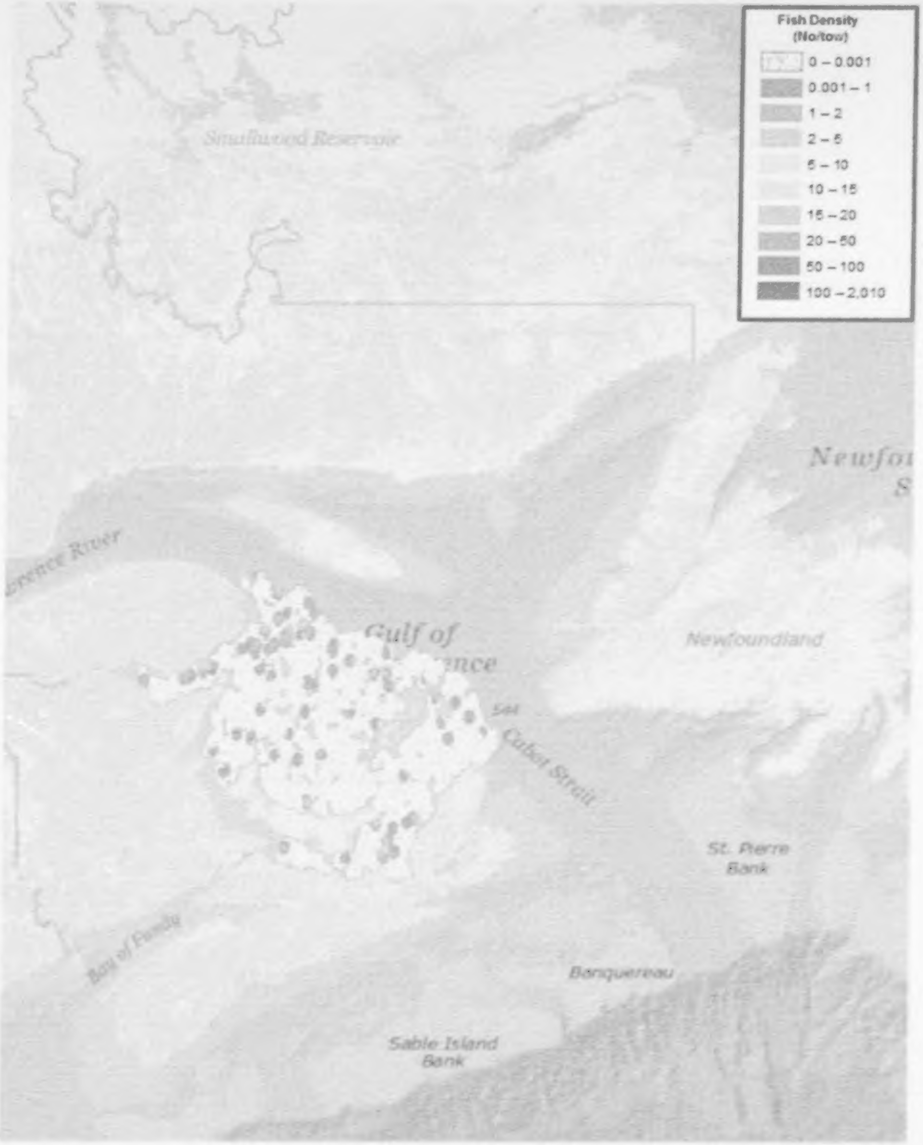

Fish Density (No/tow)
0 – 0.001
0.001 – 1
1 – 2
2 – 5
5 – 10
10 – 15
15 – 20
20 – 50
50 – 100
100 – 2,010
Smallwood Reservoir
Newfo
rence River
Gulf of
ence
544
Cabot Strait
Newfoundland
St. Pierre Bank
Bay of Fundy
Banquereau
Sable Island Bank

Figure 43. Kernel density plot of the DFO-Gulf research survey of Div. 4T, 2005-14.

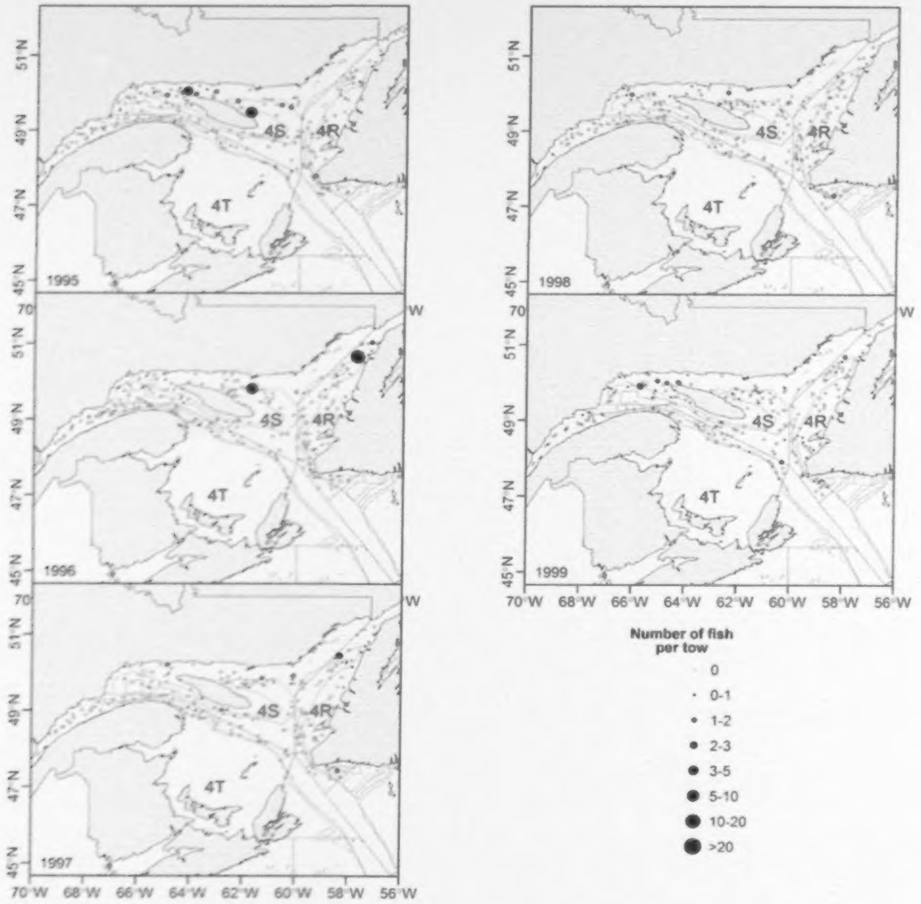

51°N
49°N
47°N
45°N
4S
4R
4T
1995
1996
1997
1998
1999
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 44. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-QC research survey of nGSL, 1995-99.

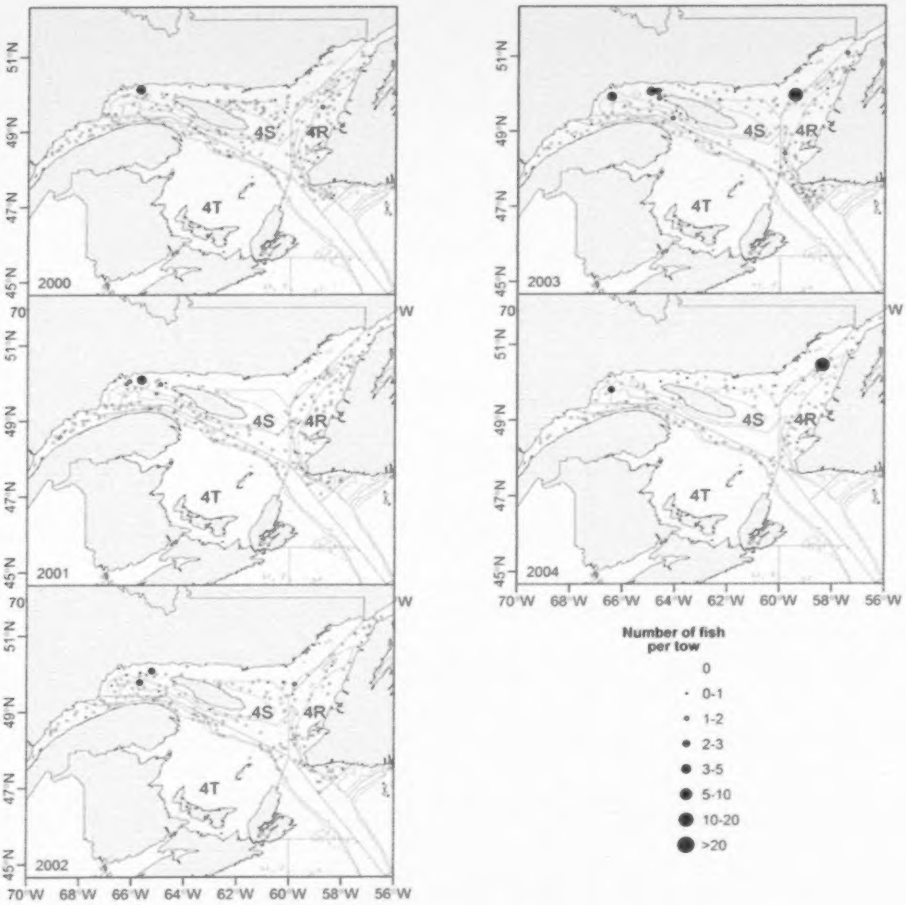

2000
2001
2002
2003
2004
4S
4R
4T
45°N
47°N
49°N
51°N
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 45. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-QC research survey of nGSL, 2000-04.

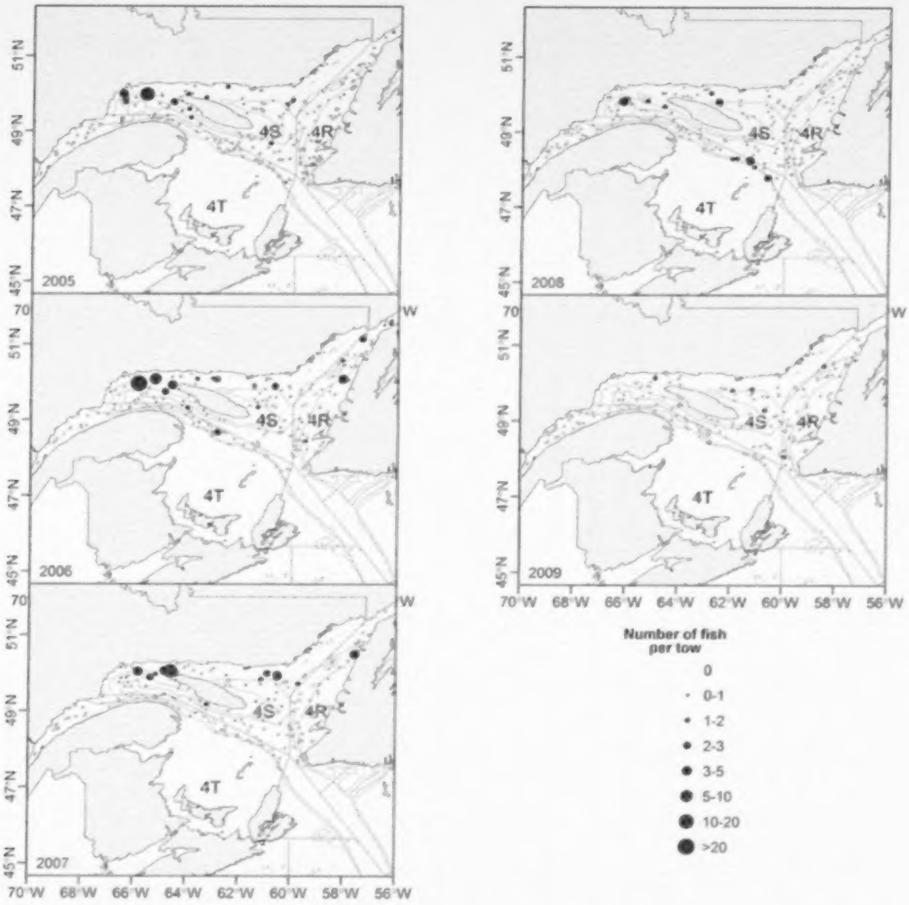

2005
2006
2007
2008
2009
4S
4R
4T
51°N
49°N
47°N
45°N
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 46. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-QC research survey of nGSL, 2005-09.

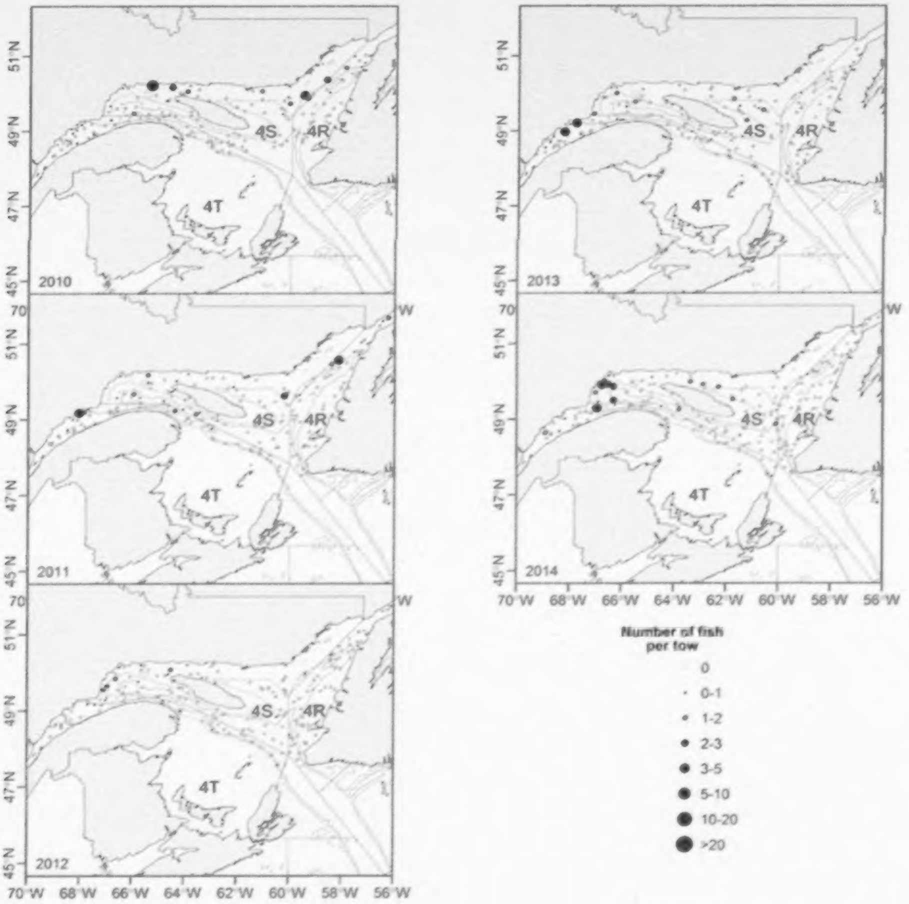

2010
2011
2012
2013
2014
4S
4R
4T
45°N
47°N
49°N
51°N
70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 47. Distribution of catches (number of fish/tow) of Common Lumpfish based on DFO-QC research survey of nGSL, 2010-14.

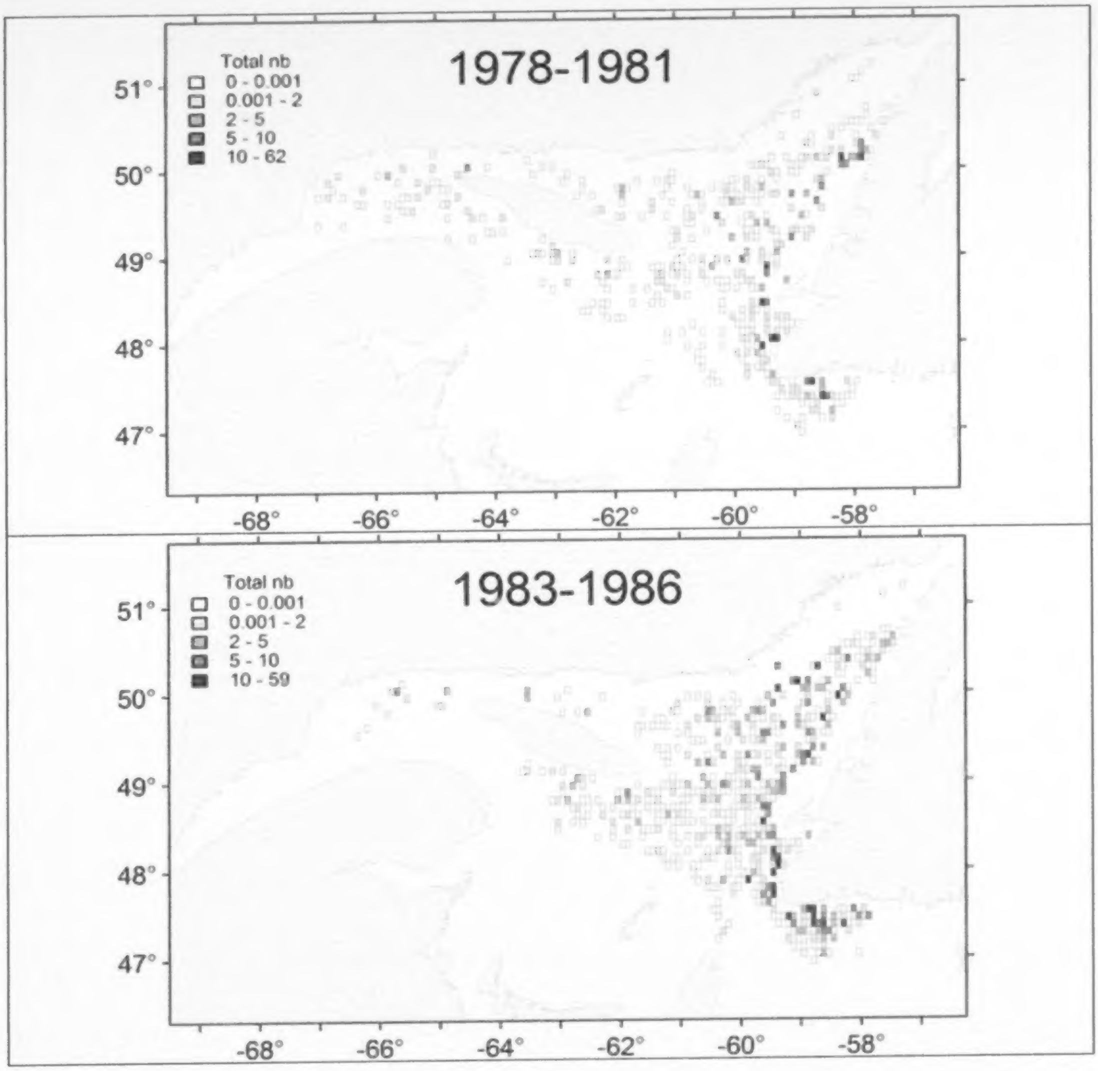

Total nb
☐ 0 - 0.001
☐ 0.001 - 2
▨ 2 - 5
▨ 5 - 10
■ 10 - 62
1978-1981
51°
50°
49°
48°
47°
-68°
-66°
-64°
-62°
-60°
-58°
Total nb
☐ 0 - 0.001
☐ 0.001 - 2
▨ 2 - 5
▨ 5 - 10
■ 10 - 59
1983-1986
51°
50°
49°
48°
47°
-68°
-66°
-64°
-62°
-60°
-58°

Figure 48. Distribution of Common Lumpfish (sum of number per tow) per grid in DFO-QC January Engel surveys of the northern Gulf of St. Lawrence (nGSL; Divs. 4RST, Subdiv. 3Pn), 1978-86.

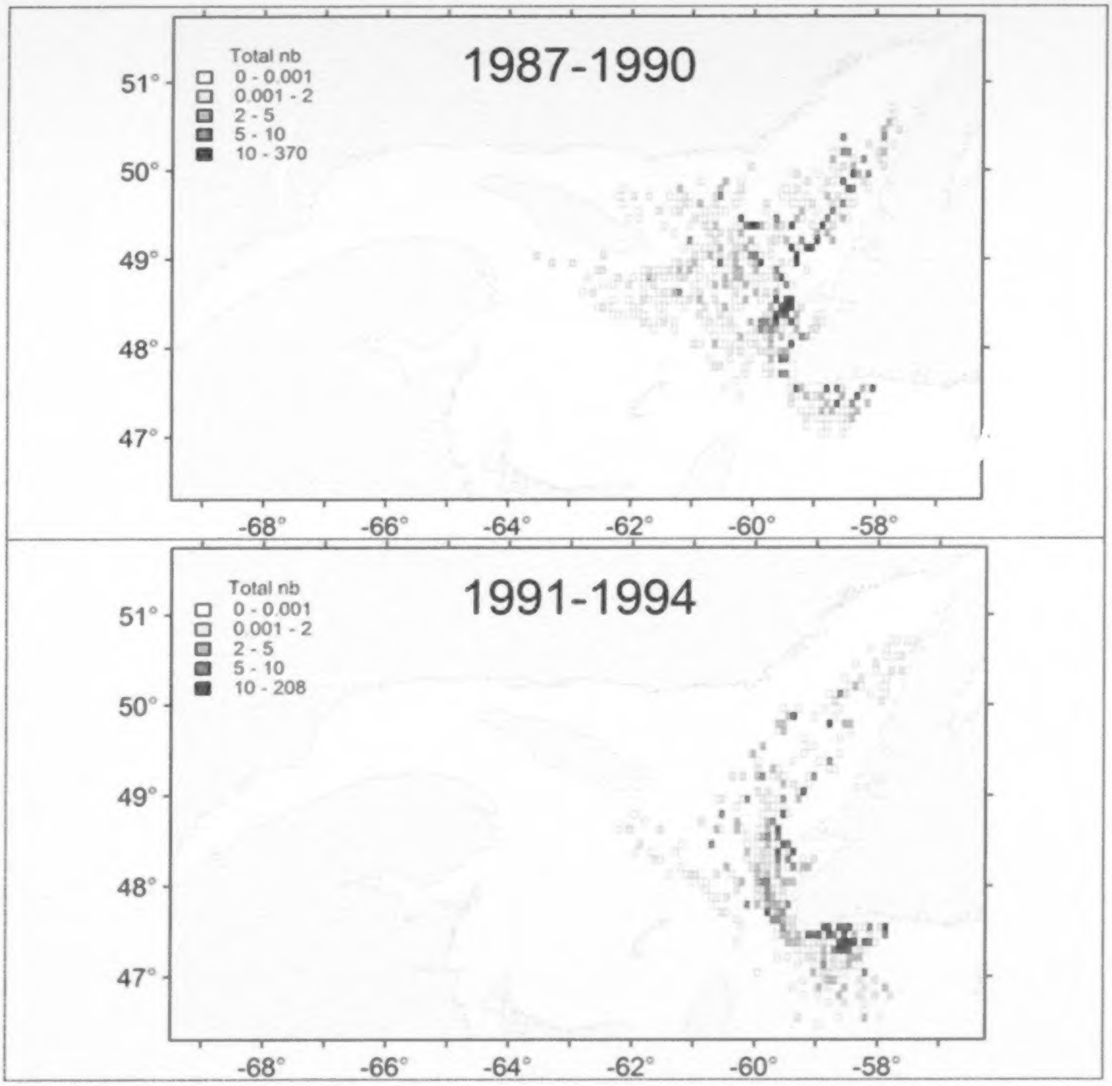

Total nb
0 - 0.001
0.001 - 2
2 - 5
5 - 10
10 - 370
1987-1990
51°
50°
49°
48°
47°
-68°
-66°
-64°
-62°
-60°
-58°
Total nb
0 - 0.001
0.001 - 2
2 - 5
5 - 10
10 - 208
1991-1994
51°
50°
49°
48°
47°
-68°
-66°
-64°
-62°
-60°
-58°

Figure 49. Distribution of Common Lumpfish (sum of number per tow) per grid in DFO-QC January Engel surveys of the nGSL (Divs. 4RST, Subdiv. 3Pn), 1987-94.

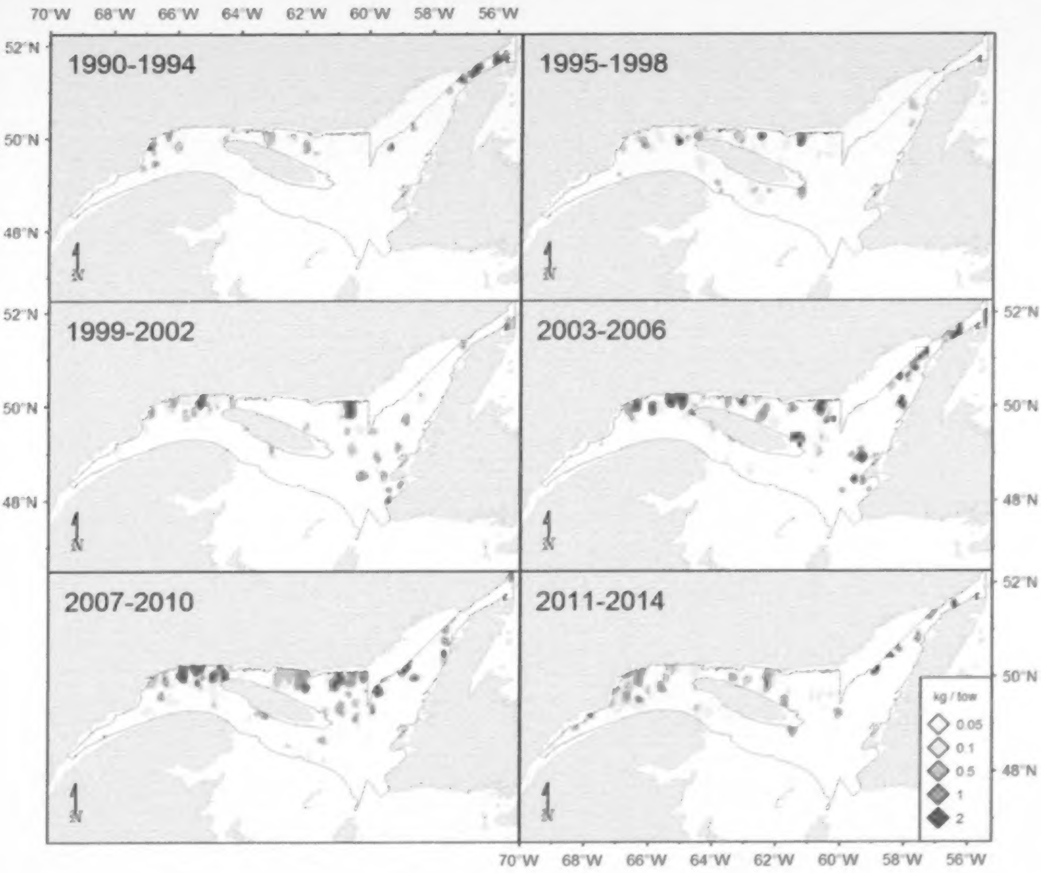

70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
52°N
50°N
48°N
1990-1994
1995-1998
1999-2002
2003-2006
2007-2010
2011-2014
N
kg / tow
0.05
0.1
0.5
1
2

Figure 50. Distribution of Common Lumpfish catches (standardized weight in kgs per tow) in DFO-QC nGSL August surveys, 1990-2014. Solid black line defines the perimeter of the surveyed area.

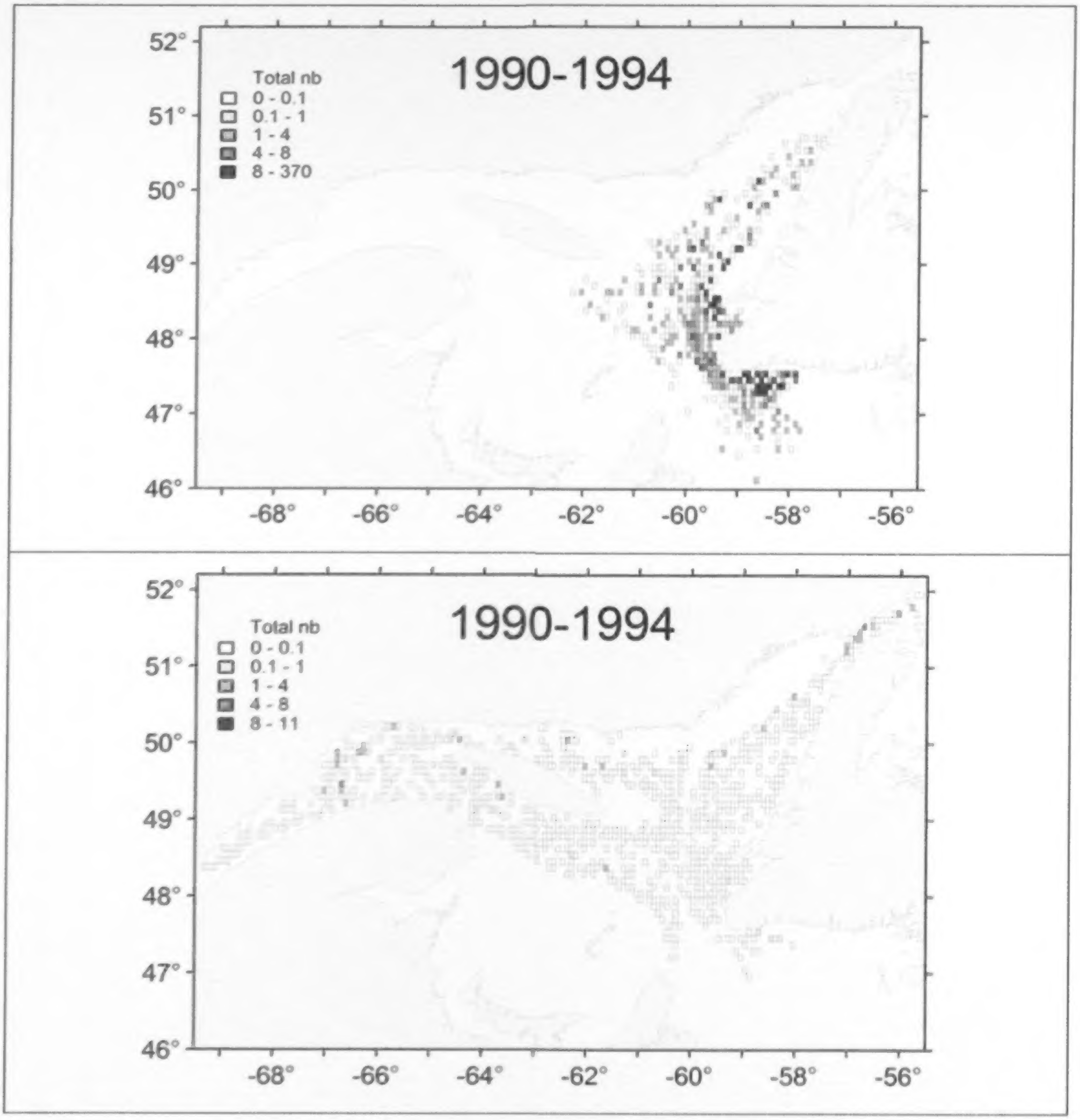

1990-1994
Total nb
☐ 0 - 0.1
☐ 0.1 - 1
▨ 1 - 4
▨ 4 - 8
■ 8 - 370
52°
51°
50°
49°
48°
47°
46°
-68°
-66°
-64°
-62°
-60°
-58°
-56°
1990-1994
Total nb
☐ 0 - 0.1
☐ 0.1 - 1
▨ 1 - 4
▨ 4 - 8
■ 8 - 11
52°
51°
50°
49°
48°
47°
46°
-68°
-66°
-64°
-62°
-60°
-58°
-56°

Figure 51. Seasonal distribution of Common Lumpfish catches (total number of fish/grid cell) in DFO-QC nGSL surveys in 1990-94: Winter-January (top panel), and Summer-August (bottom panel).

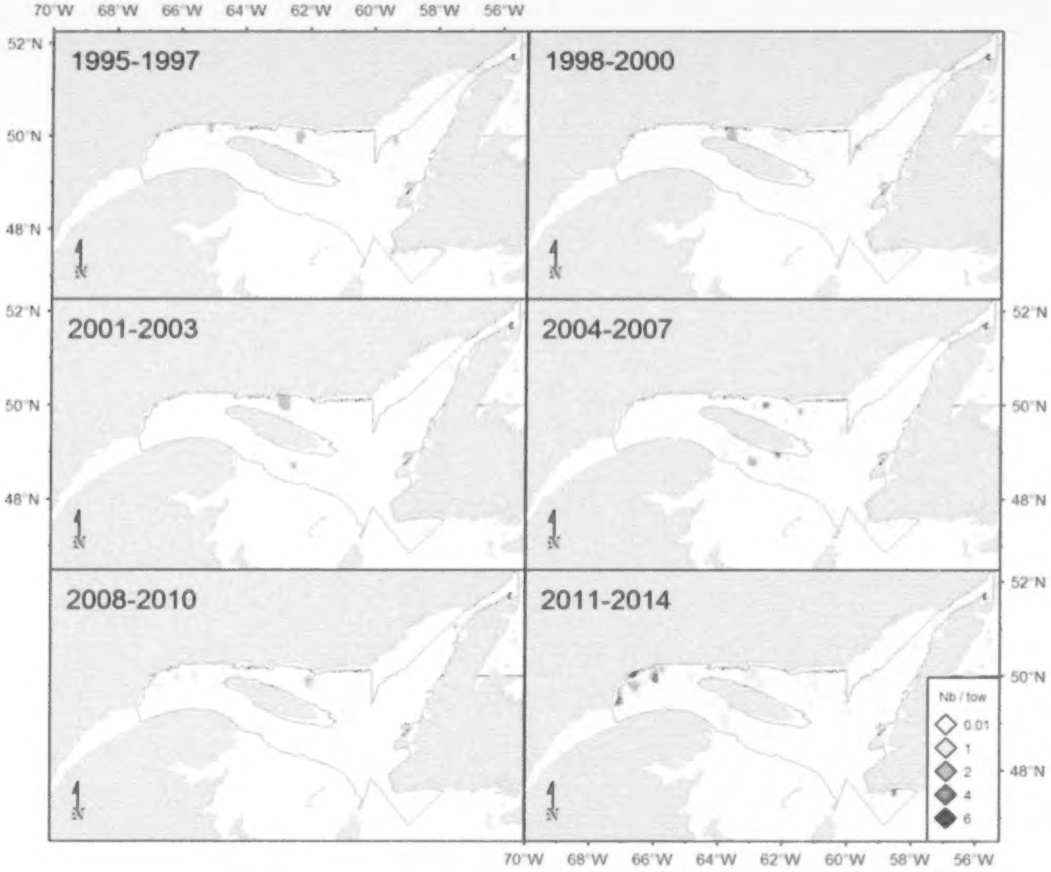

70°W
68°W
66°W
64°W
62°W
60°W
58°W
56°W
52°N
50°N
48°N
1995-1997
1998-2000
2001-2003
2004-2007
2008-2010
2011-2014
N
Nb / tow
0.01
1
2
4
6

Figure 52. Distribution of Common Lumpfish catches (standardized number per tow) in nGSL July Sentinel surveys, 1995-2014. Solid black line defines the perimeter of the surveyed area.

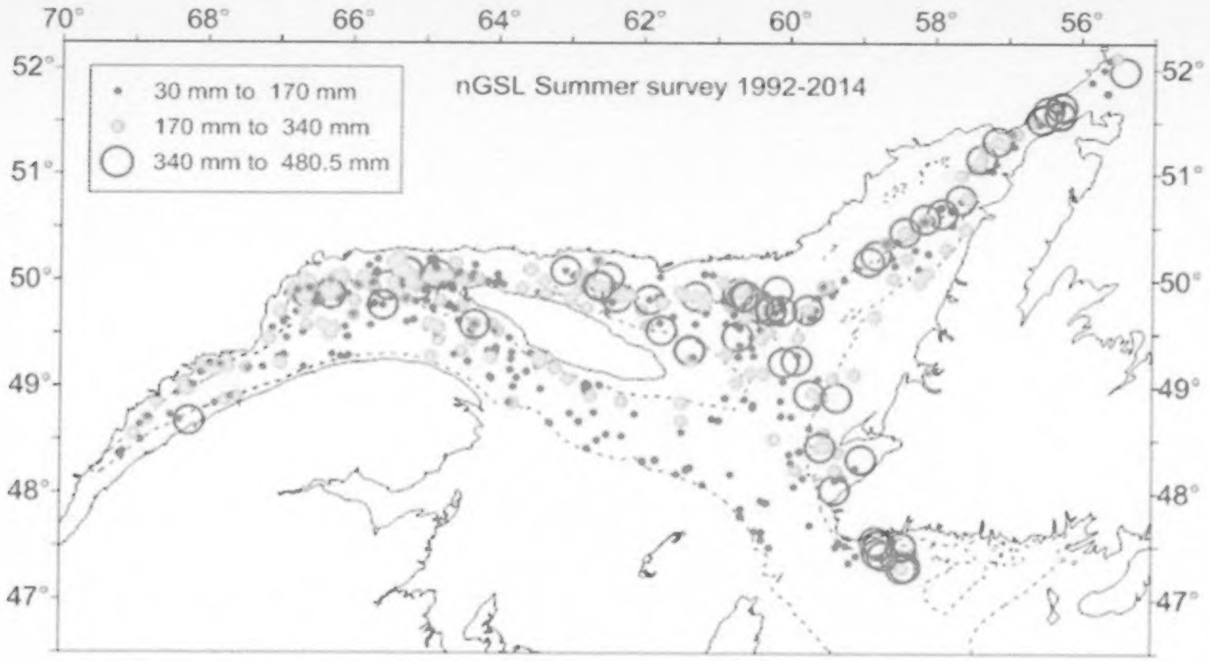

70°
68°
66°
64°
62°
60°
58°
56°
52°
51°
50°
49°
48°
47°
30 mm to 170 mm
170 mm to 340 mm
340 mm to 480.5 mm
nGSL Summer survey 1992-2014

Figure 53. Distribution of Common Lumpfish by size classes in the nGSL summer August survey, 1992-2014.

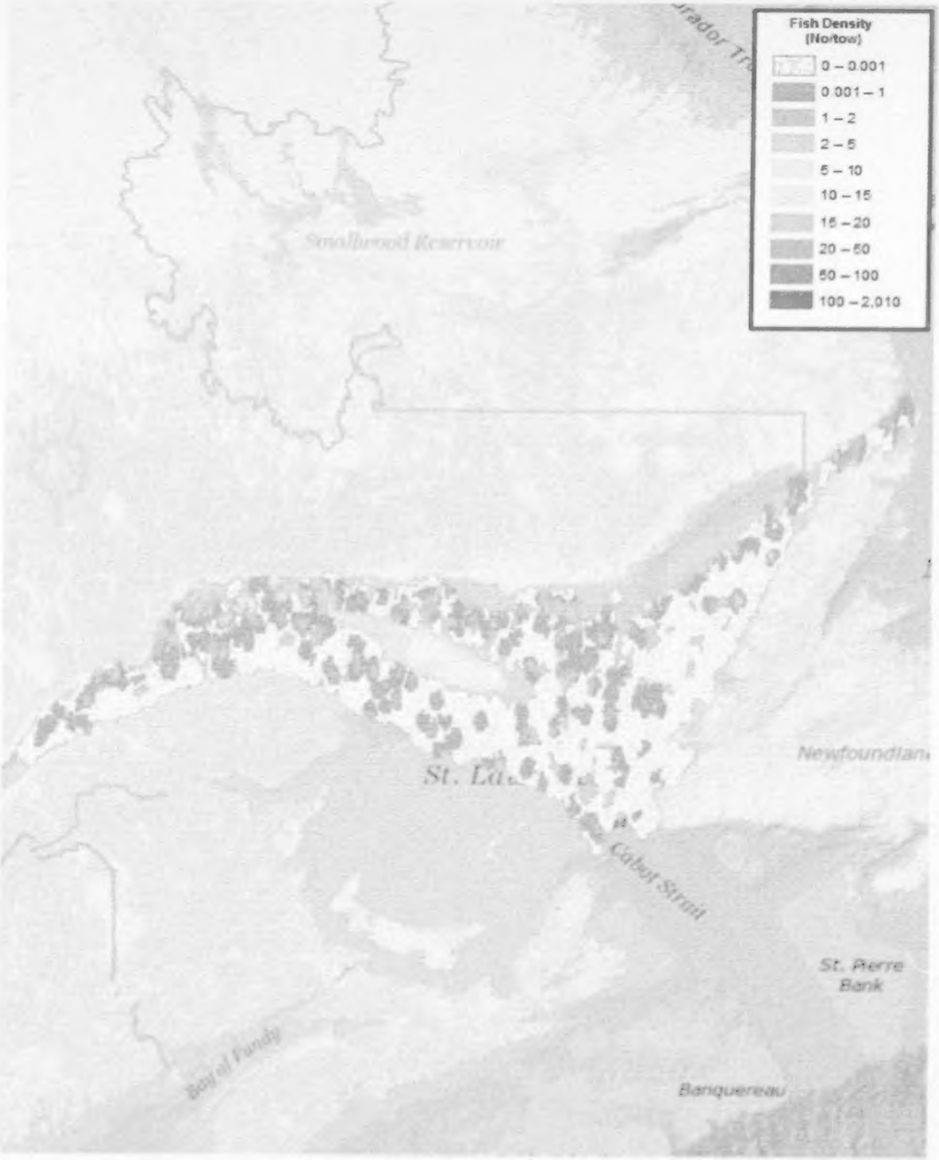

Fish Density
(No/tow)
0 – 0.001
0.001 – 1
1 – 2
2 – 5
5 – 10
10 – 15
15 – 20
20 – 50
50 – 100
100 – 2,010
Smallwood Reservoir
St. La
Cabot Strait
Newfoundlan
St. Pierre Bank
Bay of Fundy
Banquereau

Figure 54. Kernel density plot of DFO-QC research survey catches of Common Lumpfish in nGSL, 2005-14.

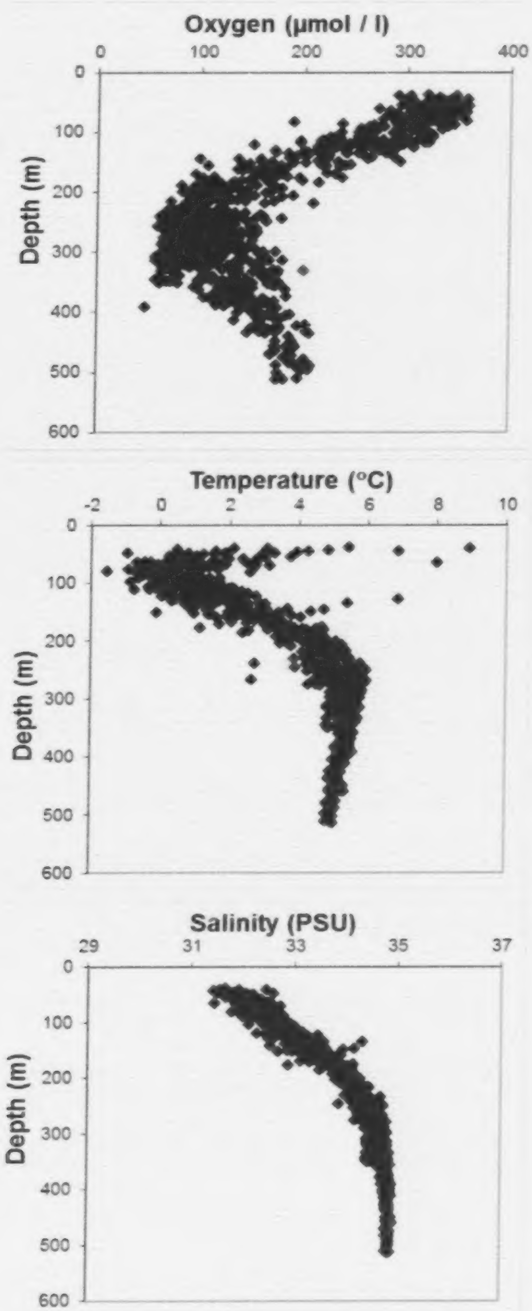


Figure 55. Characteristics of survey sites in DFO-QC Estuary and nGSL research surveys, 1990-2014.

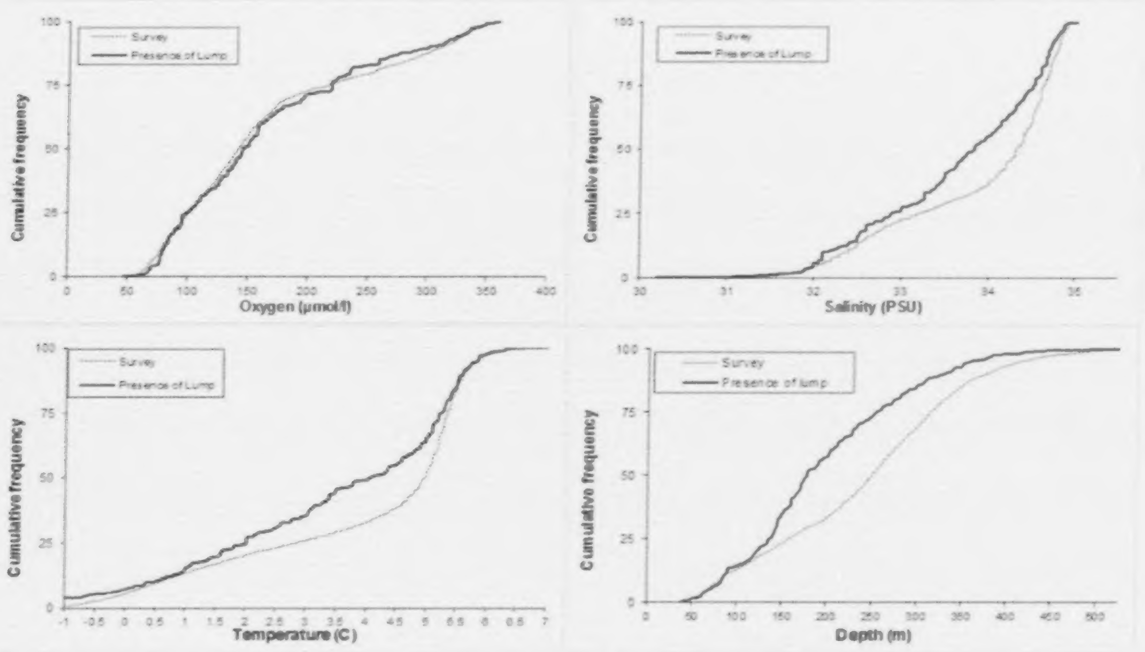


Figure 56. Cumulative frequency distributions of Common Lumpfish oxygen, salinity, temperature, and depth associations in DFO-QC nGSL August surveys, 1990-2014.

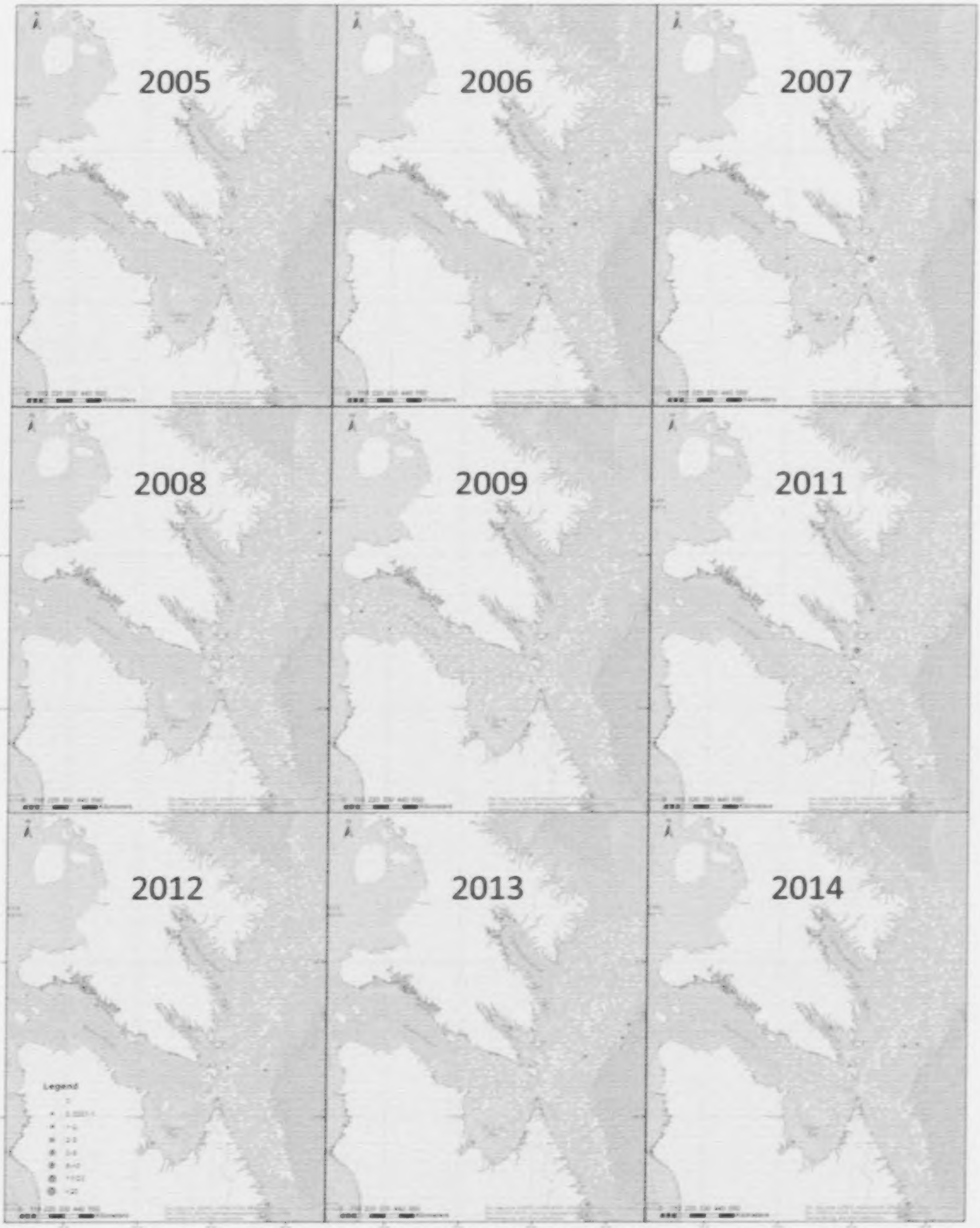

2005
2006
2007
2008
2009
2011
2012
2013
2014
Legend

Figure 57. Distribution of Common Lumpfish catches (standardized number per tow) in DFO-C&A surveys of Subarea 0, 2005-14. No Common Lumpfish were caught in 2010.

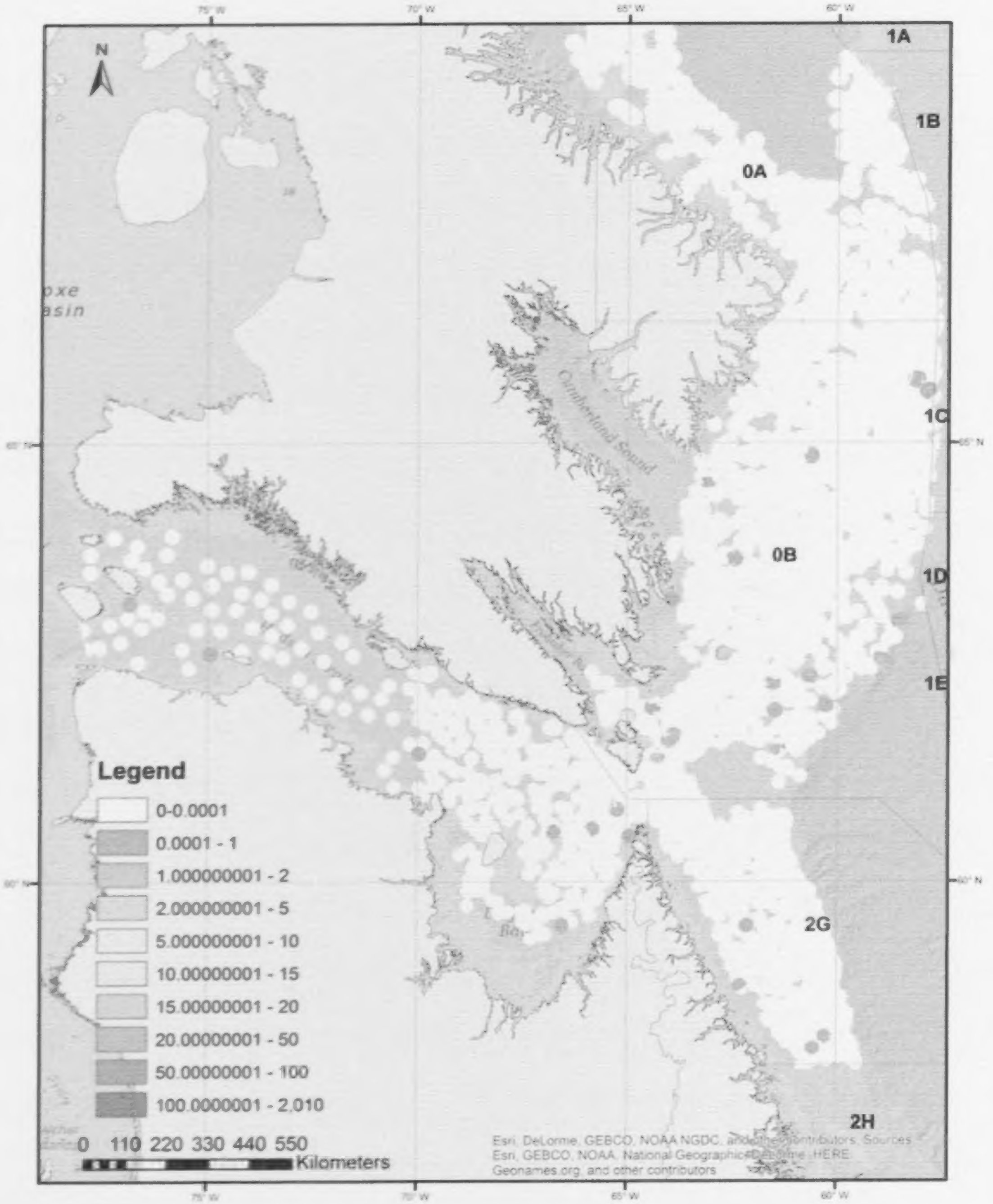

75° W
70° W
65° W
60° W
N
1A
1B
0A
1C
65° N
Cumberland Sound
0B
1D
1E
2G
60° N
2H
Legend
0-0.0001
0.0001 - 1
1.000000001 - 2
2.000000001 - 5
5.000000001 - 10
10.00000001 - 15
15.00000001 - 20
20.00000001 - 50
50.00000001 - 100
100.0000001 - 2,010
0 110 220 330 440 550
Kilometers
Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors, Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors

Figure 58. Kernel density plot of Common Lumpfish catches in DFO-C&A surveys of Subarea 0.

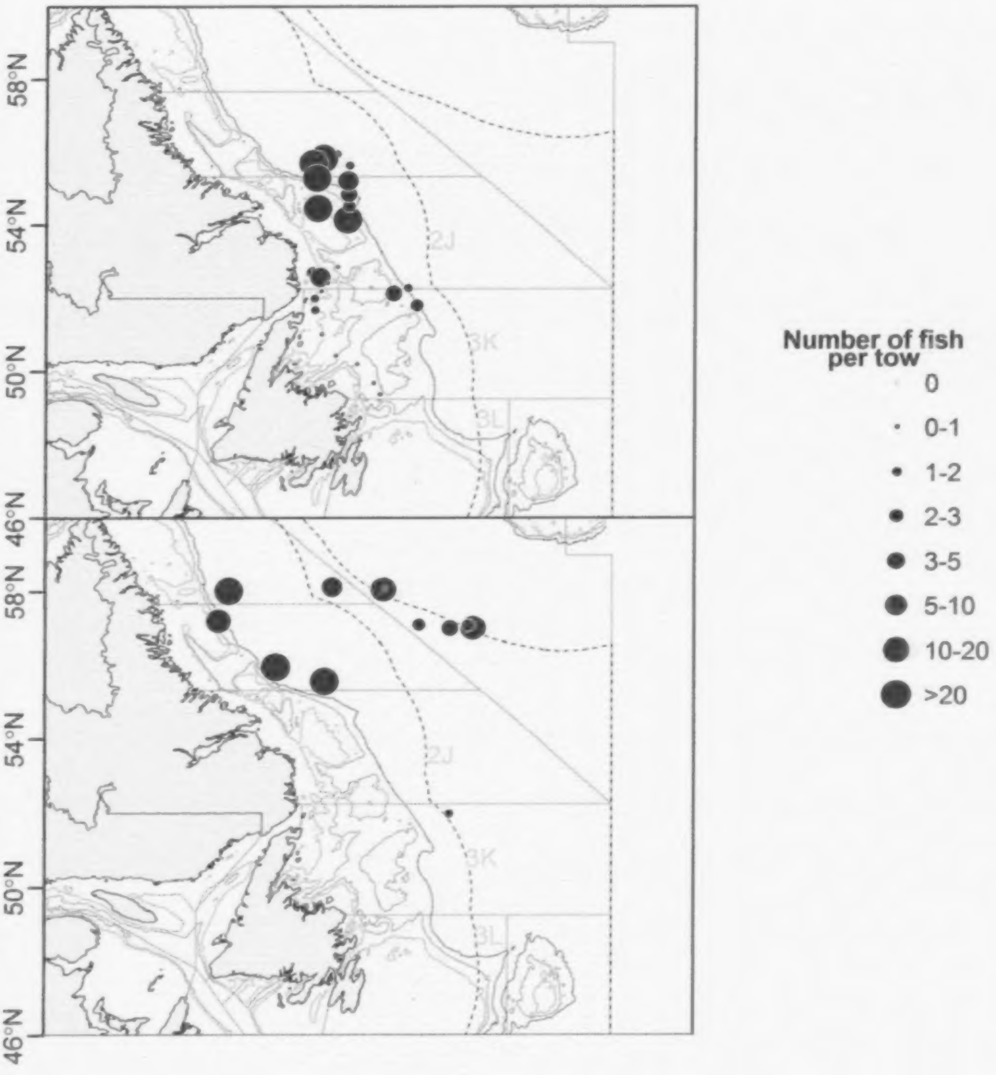

58°N
54°N
50°N
46°N
2J
3K
3L
58°N
54°N
50°N
46°N
2J
3K
3L
Number of fish per tow
0
0-1
1-2
2-3
3-5
5-10
10-20
>20

Figure 59. Distribution of Common Lumpfish catches (number of fish per tow) in the Canadian pelagic surveys of 2008 (top panel) and 2009 (bottom panel).

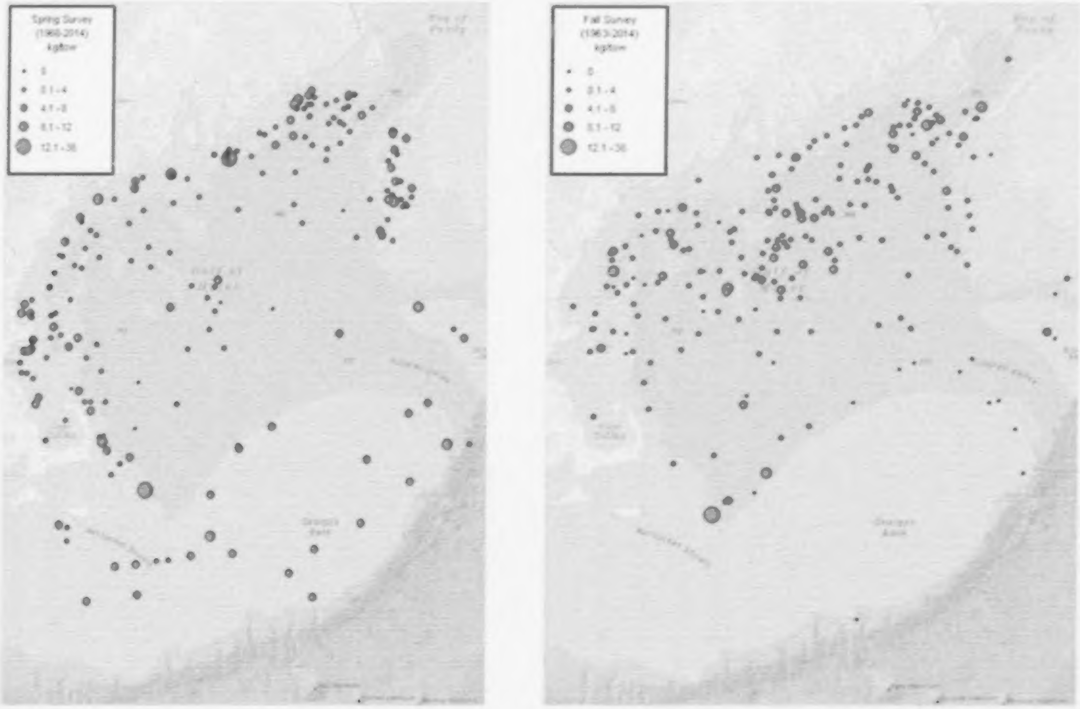
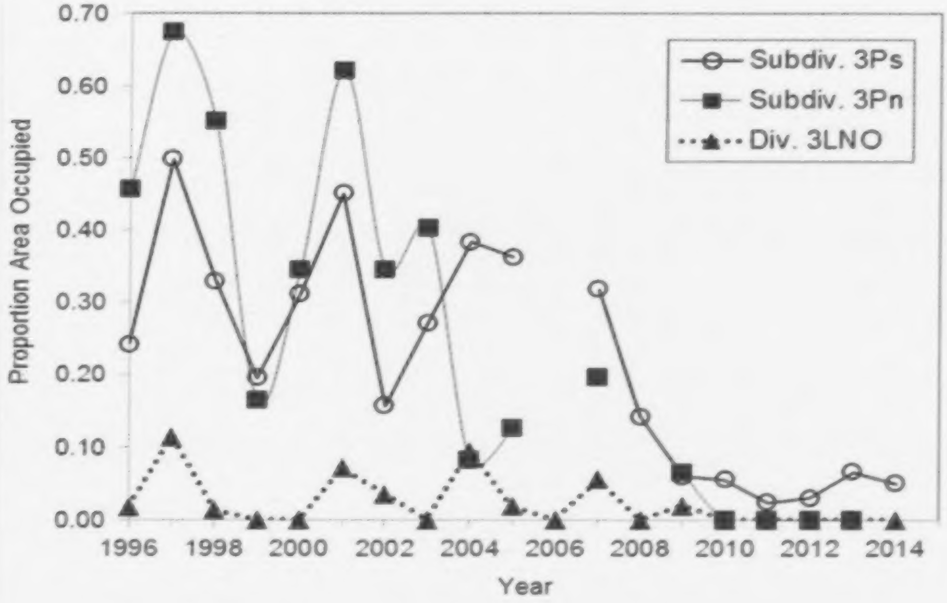

Spring Survey
(1968-2014)
kg/tow
0
0.1 - 4
4.1 - 8
8.1 - 12
12.1 - 36
Fall Survey
(1963-2014)
kg/tow
0
0.1 - 4
4.1 - 8
8.1 - 12
12.1 - 36
Georges Bank
Georges Bank

Figure 60. Distribution of Common Lumpfish catches (standardized weight in kgs per tow) in US spring (1968-2014) and fall (1963-2014) research surveys.



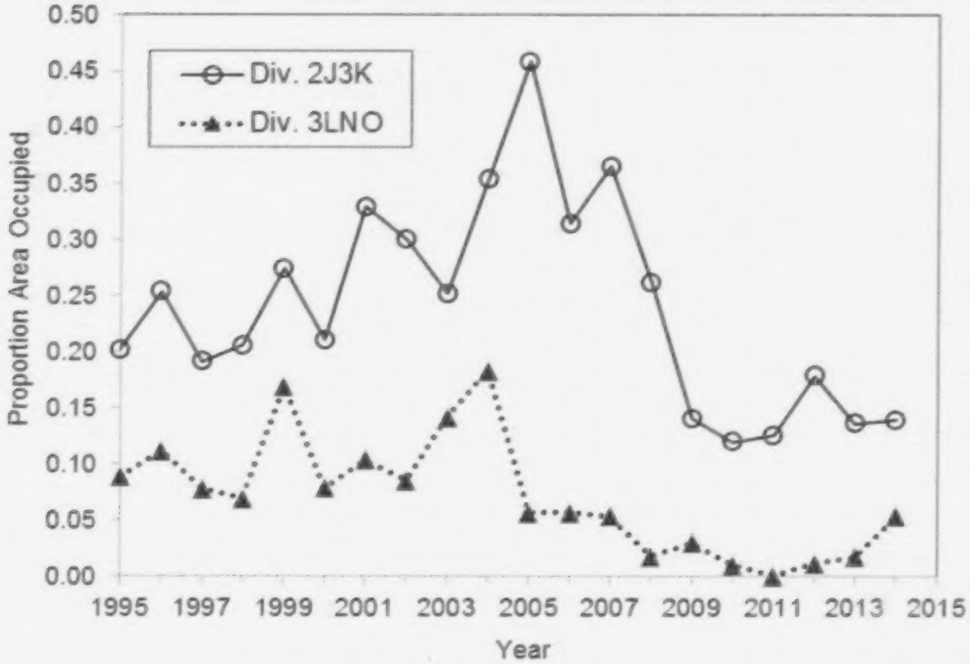


Figure 61. Proportion area occupied by Common Lumpfish from DFO-NL surveys in spring (top panel: 1996-2014) and fall (bottom panel: 1995-2014).

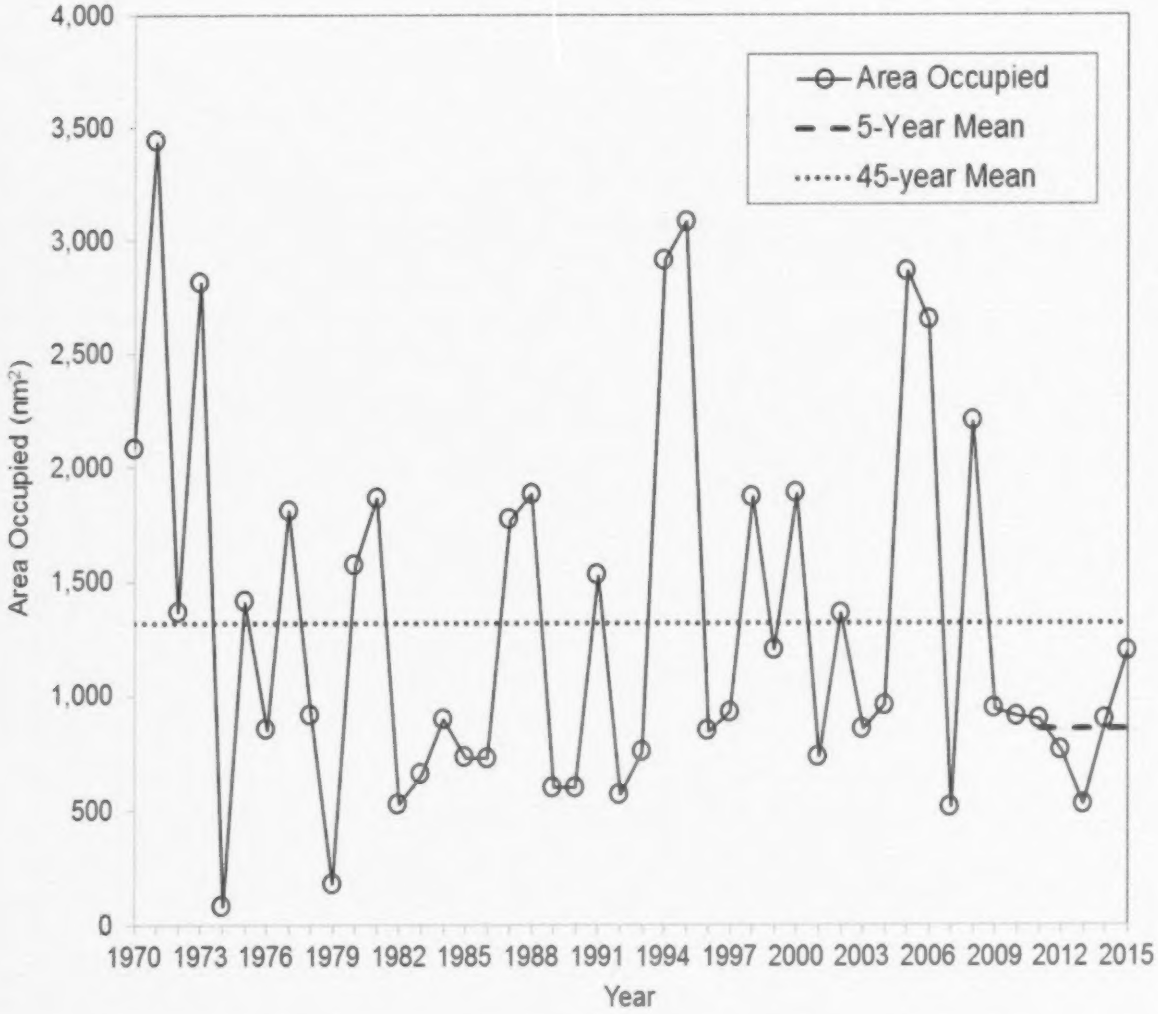
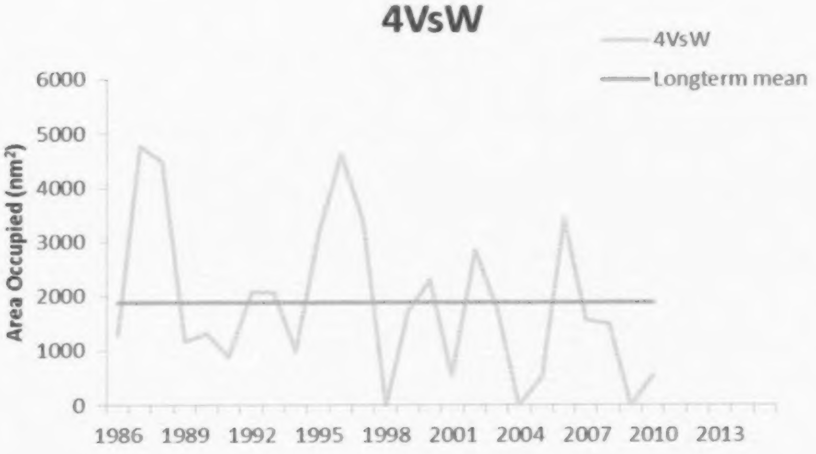


Figure 62. Area occupied (nm^2) by Common Lumpfish in DFO-MAR summer research surveys (strata 436-495).



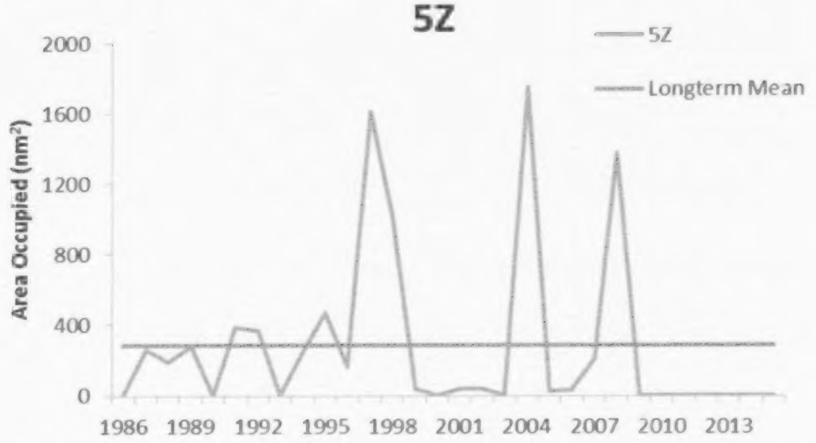


Figure 63. Design-weighted Area Occupied (km^2) by Common Lumpfish in Divs. March 4VsW research surveys (top panel) and Georges Bank winter surveys (bottom panel) from DFO-MAR.

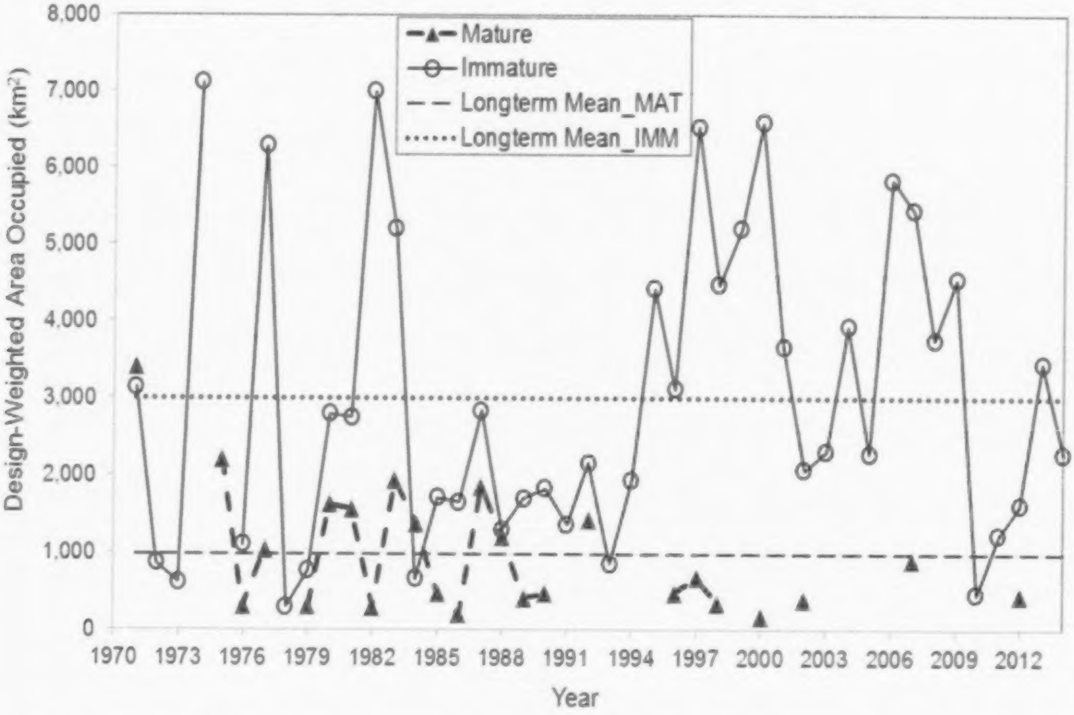


Figure 64. Design-weighted Area Occupied by Common Lumpfish in DFO-Gulf sGSL survey, 1971-2014.

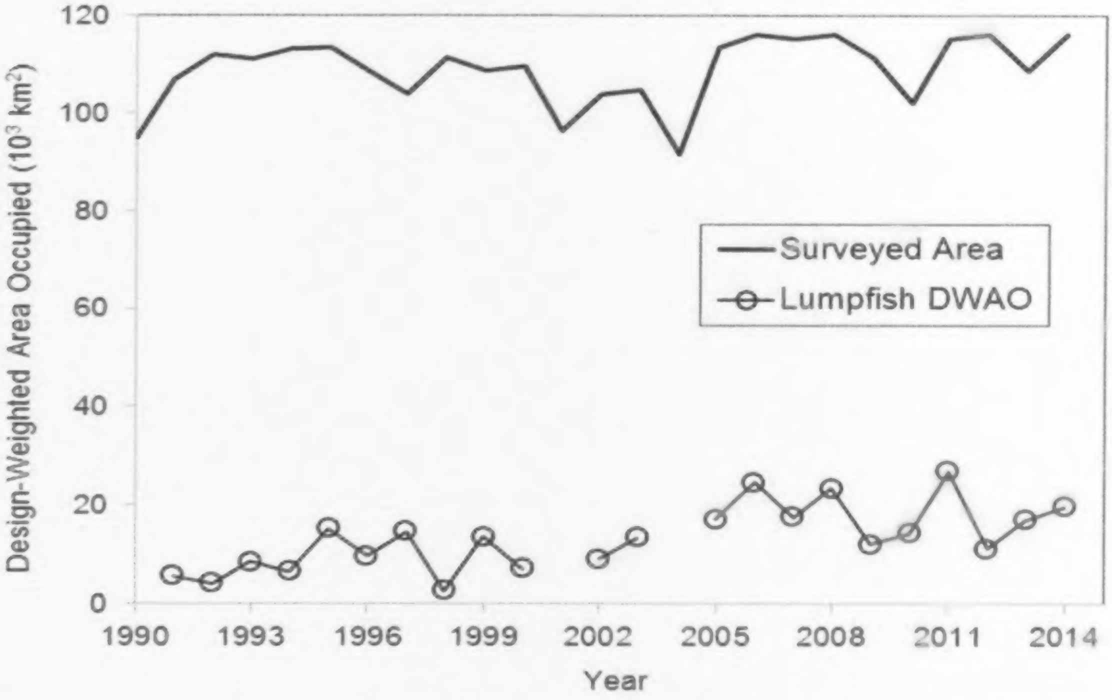


Figure 65. Design-weighted Area Occupied by Common Lumpfish in DFO-QC nGSL survey, 1991-2014.

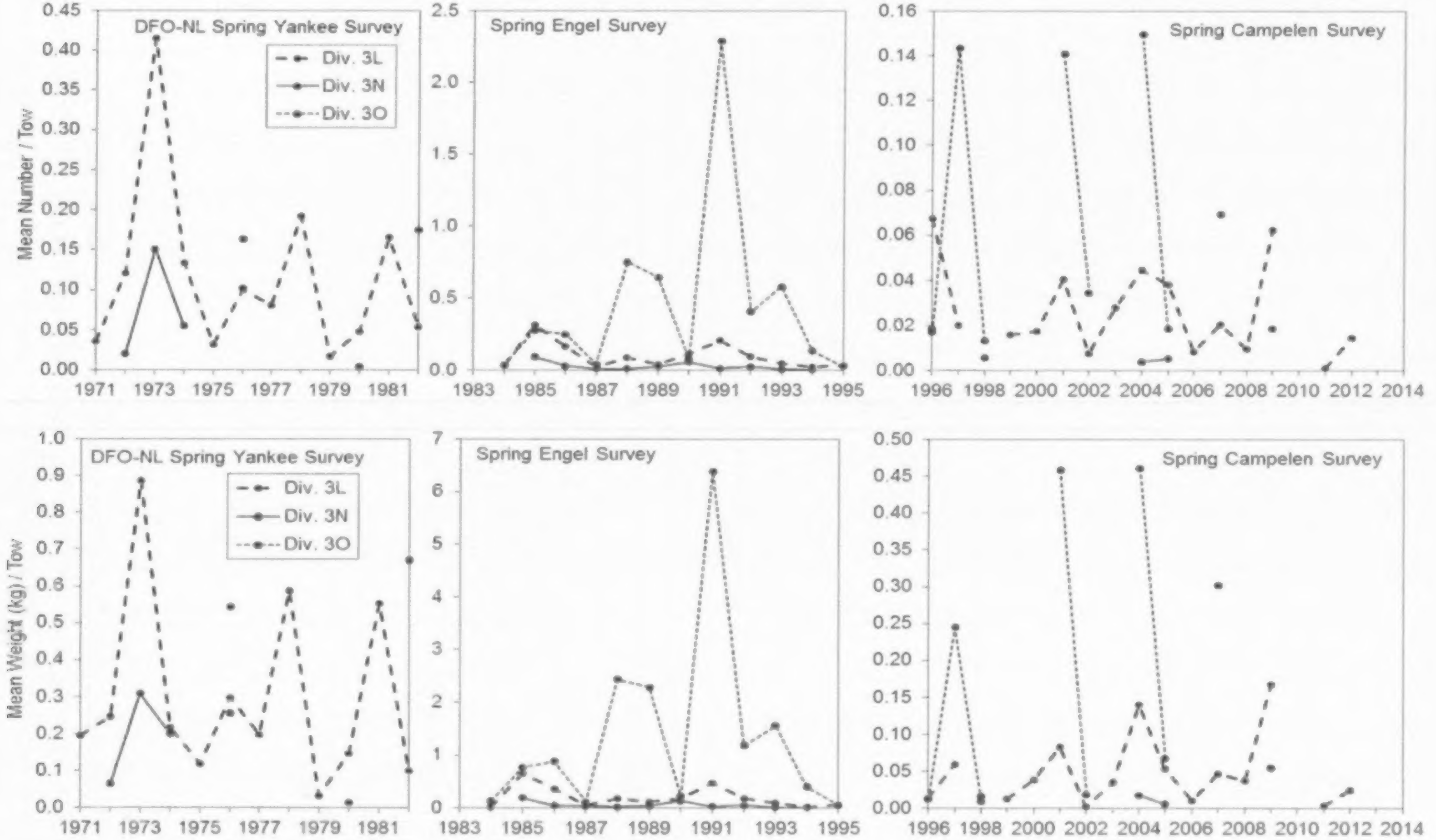


Figure 66. Mean numbers (top panels) and mean weights (kg; bottom panels) per tow of Common Lumpfish from DFO-NL spring research surveys in Divs. 3LNO. Note that Yankee, Engel, and Campelen data are not comparable.

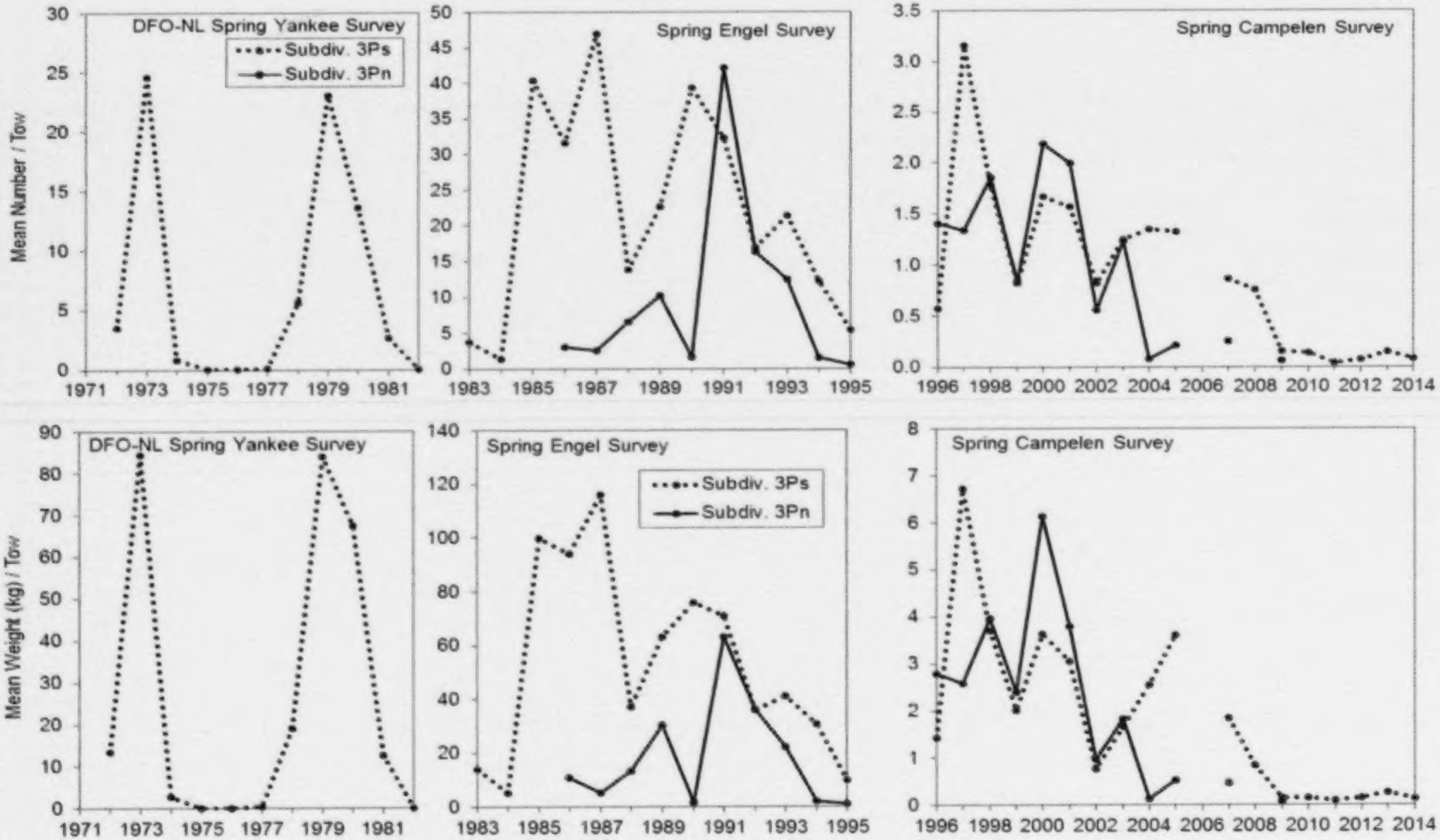


Figure 67. Mean numbers (top panels) and mean weights (kg; bottom panels) per tow of Common Lumpfish from DFO-NL spring research surveys in Div. 3P.

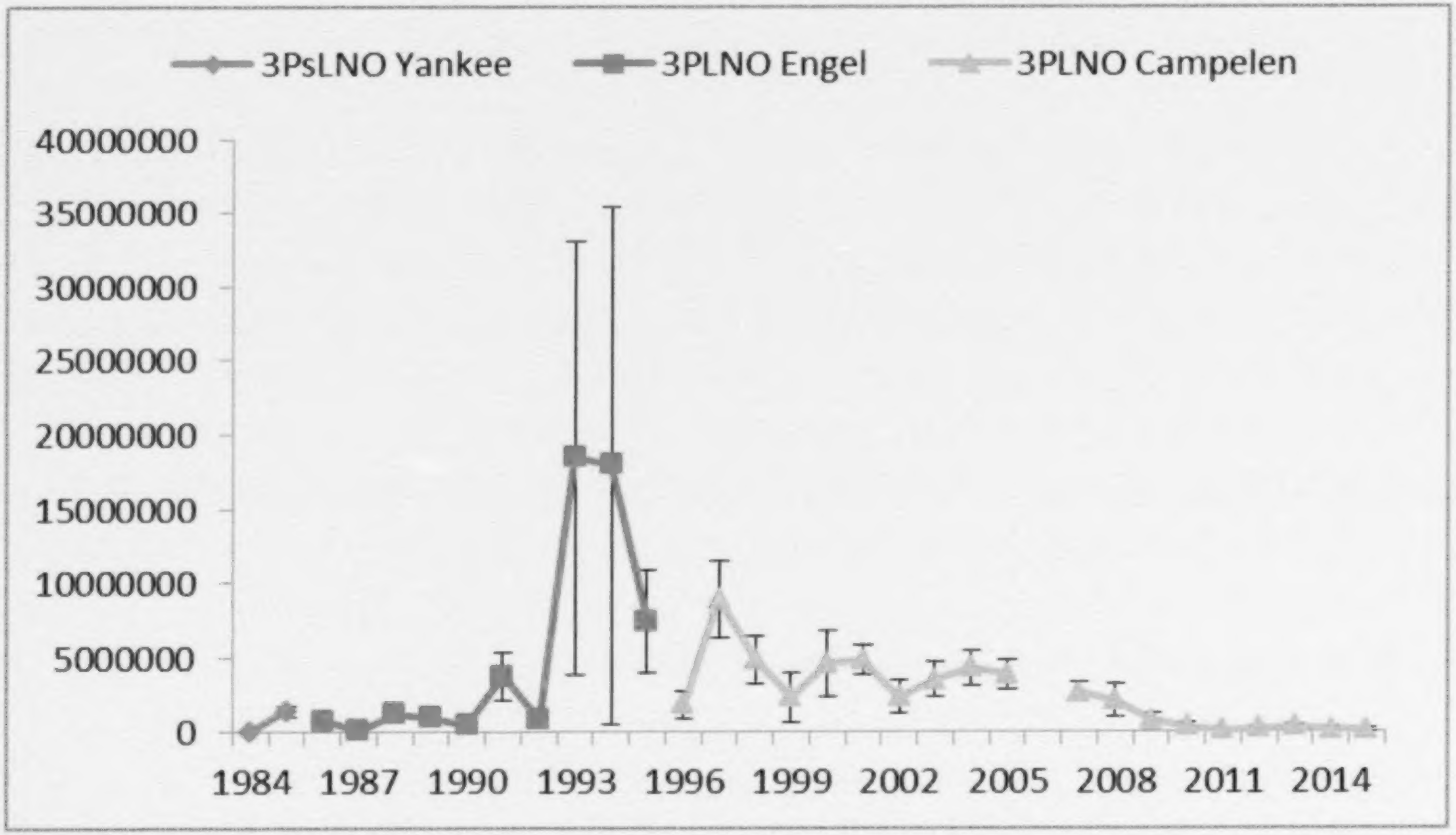


Figure 68. Total abundance of Common Lumpfish in DFO-NL Spring research surveys. Vertical bars represent 95% confidence intervals.

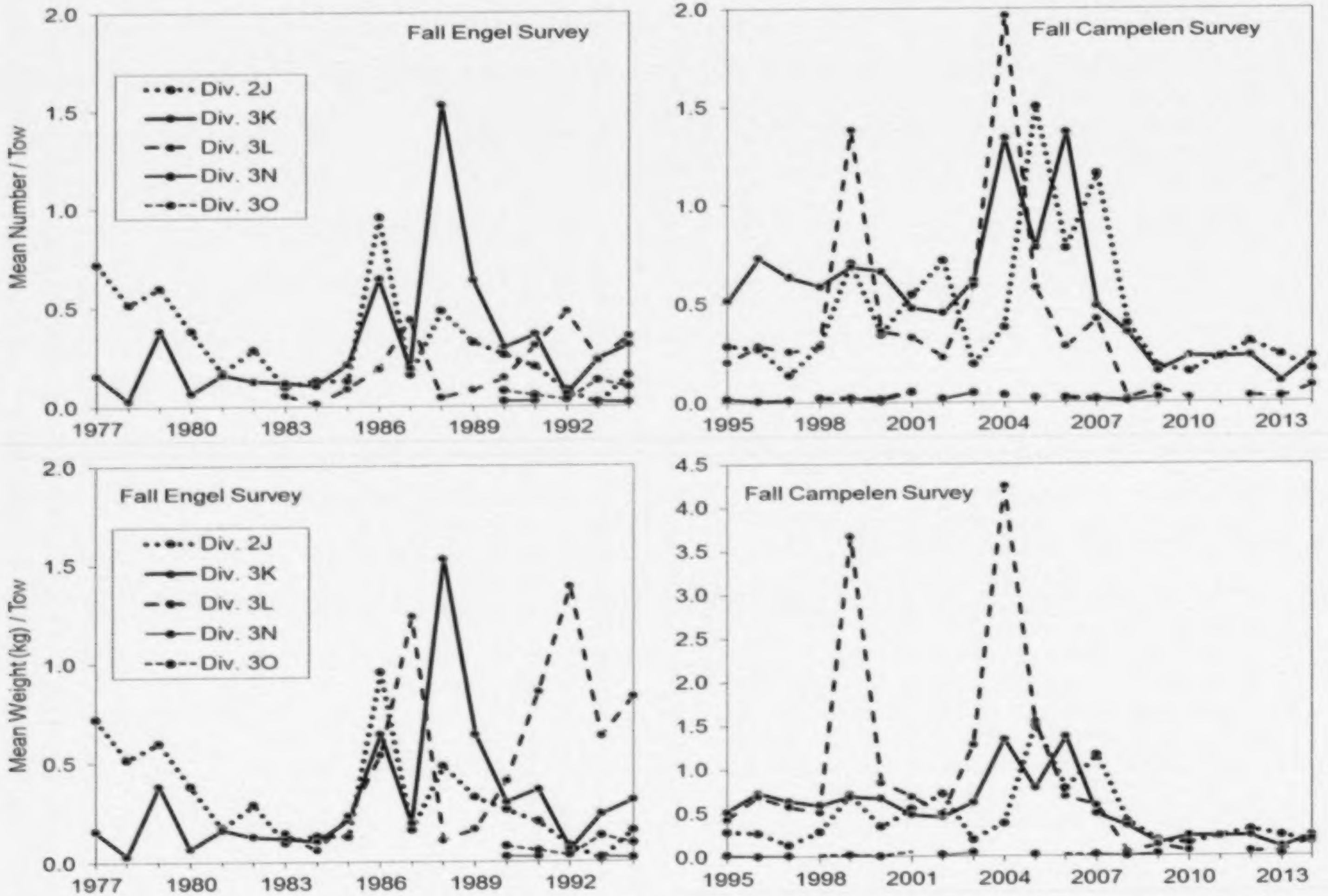


Figure 69. Mean numbers (top panels) and mean weights (kg; bottom panels) per tow of Common Lumpfish from DFO-NL fall research surveys in Divs. 2J3KLNO. Note that Engel and Campelen data are not comparable.

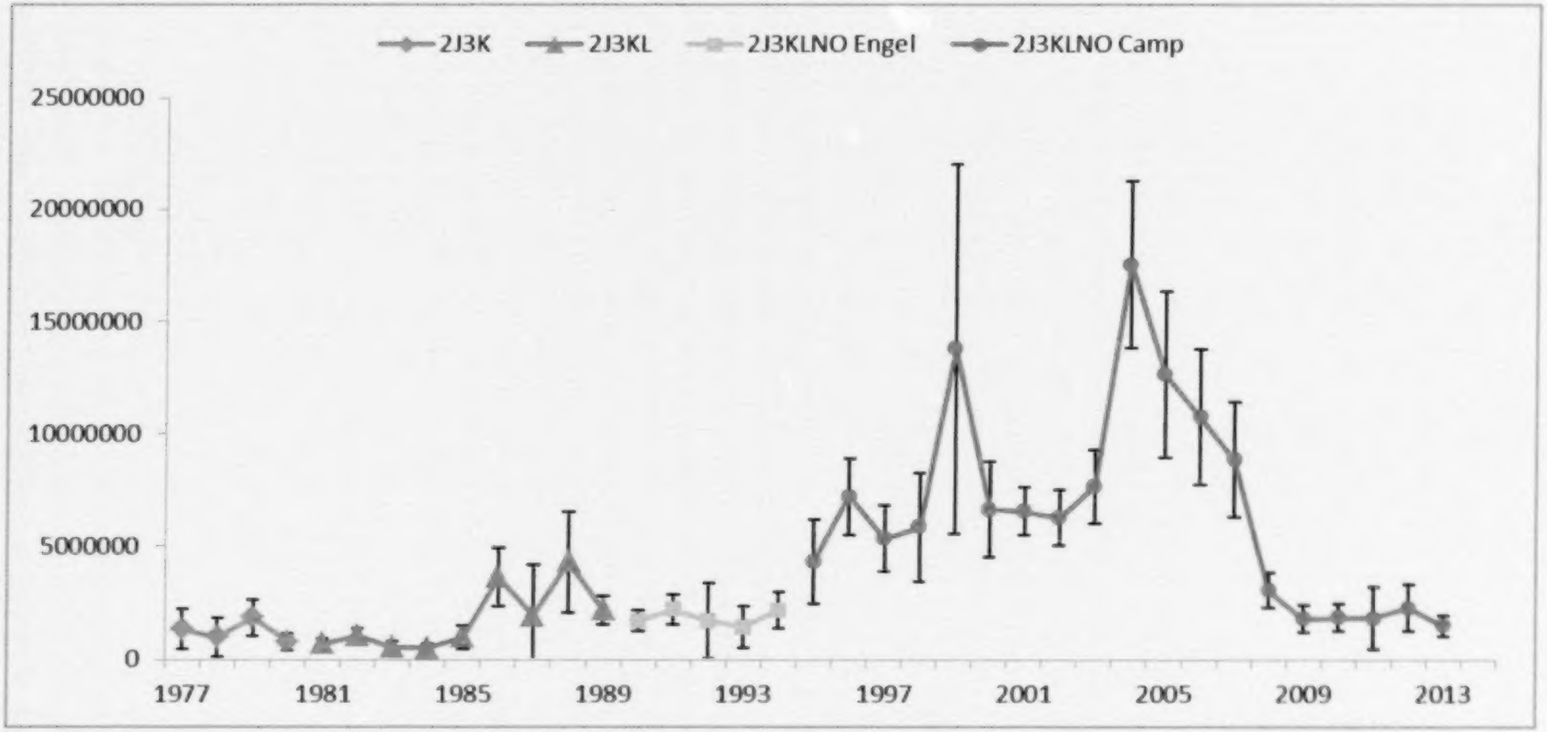


Figure 70. Total abundance of Common Lumpfish in DFO-NL Fall research surveys. Vertical bars represent 95% confidence intervals.

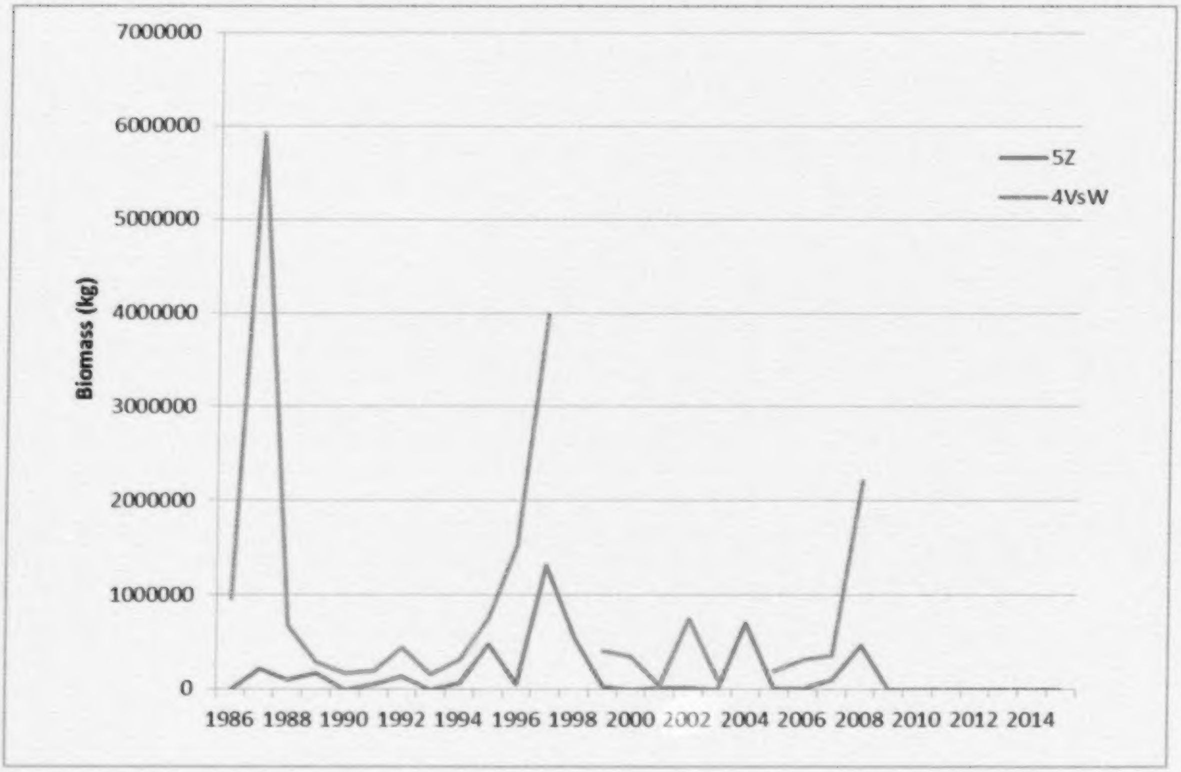


Figure 71. Total Common Lumpfish biomass (in kg) for Div. 4VsW and Div. 5Z from the DFO-MAR March 4VsW and Georges Bank winter (Div. 5Z) research surveys, 1986-2015.

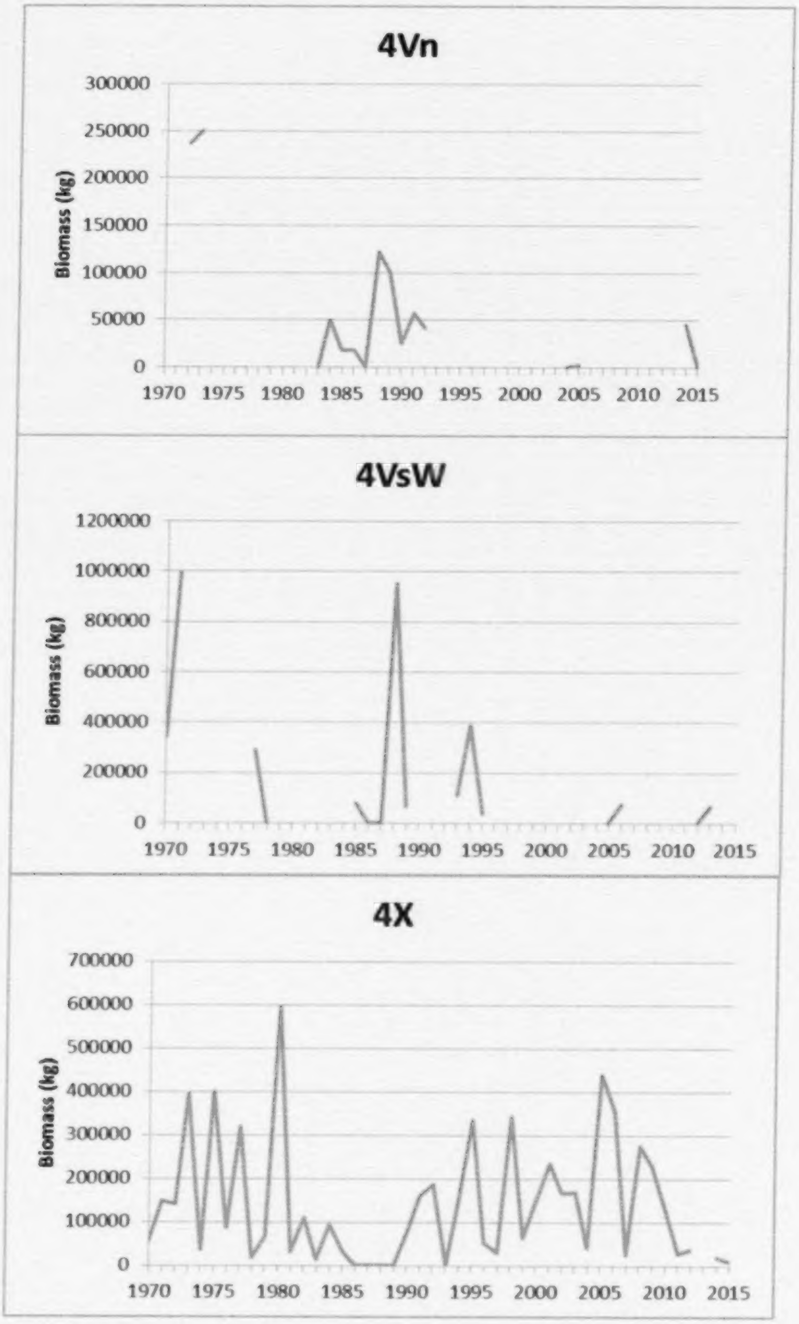


Figure 72. Total Common Lumpfish biomass (in kg) for Divs. 4Vn, 4VsW, and 4X from the DFO-MAR summer research surveys, 1970-2015.

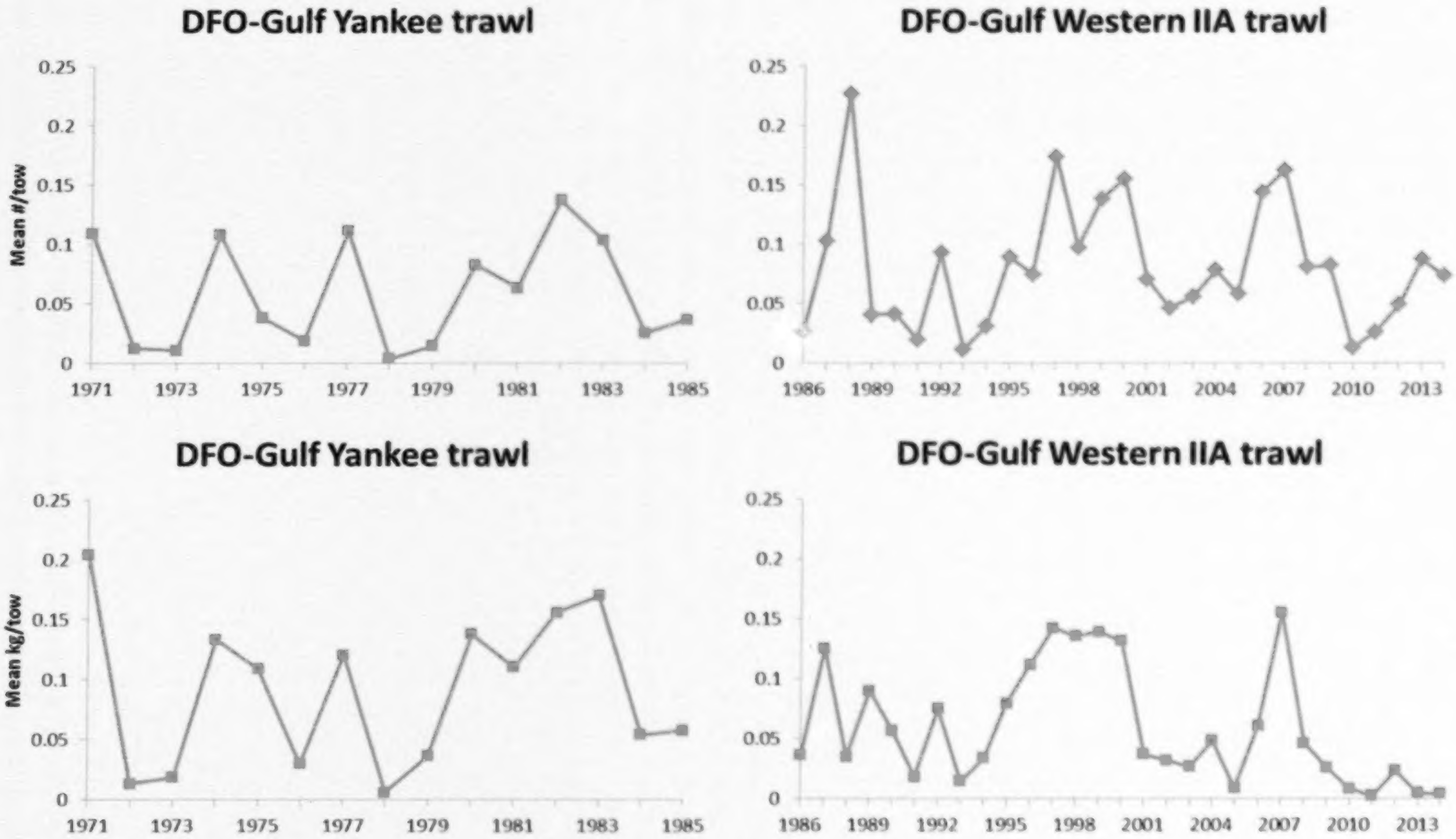


Figure 73. Abundance (mean number per tow; top panels) and biomass (mean weight in kg per tow; bottom panels) indices for all Common Lumpfish (immature+mature) in DFO-Gulf research surveys of Div. 4T, 1971-2014.

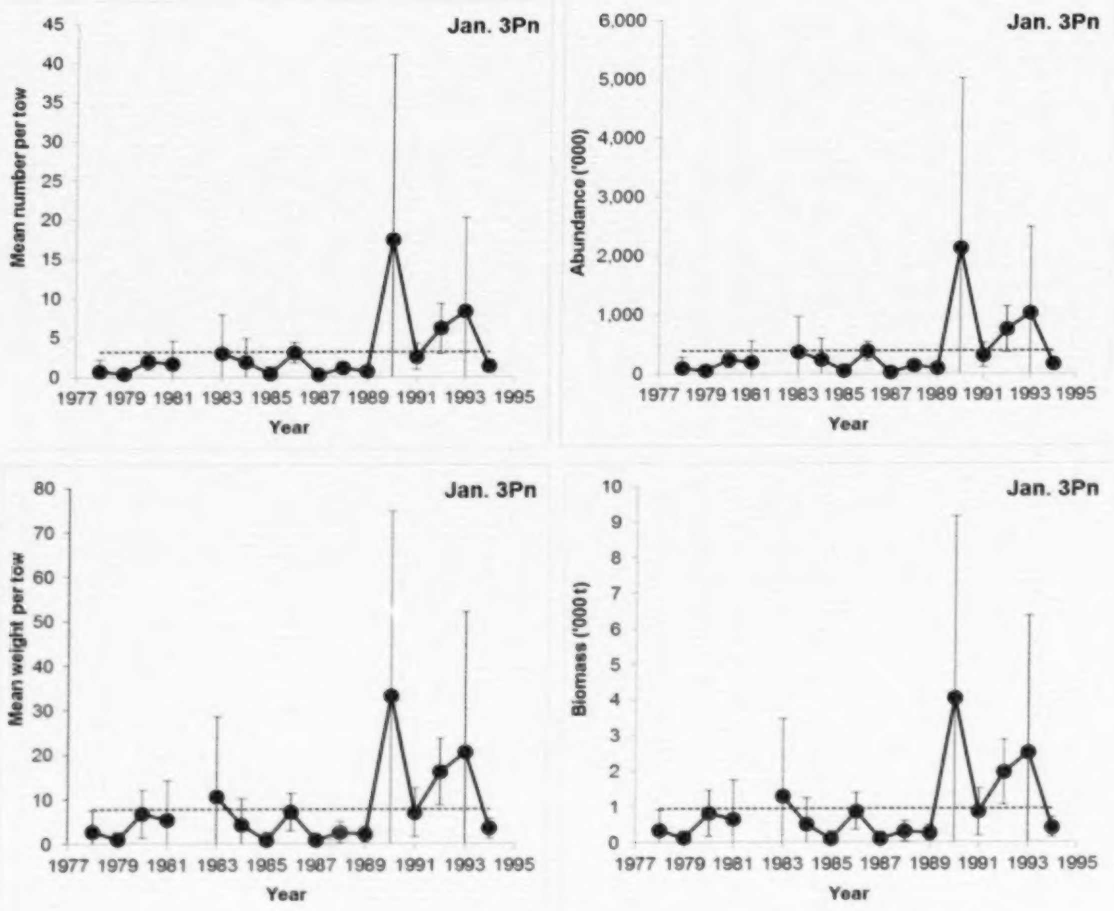


Figure 74. Common Lumpfish abundance (mean number per tow and total abundance) and biomass (mean weight in kg per tow and total biomass) indices in Subdiv. 3Pn in DFO-QC January Engel survey, 1978-94. Vertical lines represent ± 95% confidence intervals, and dashed lines represent the average of the series.

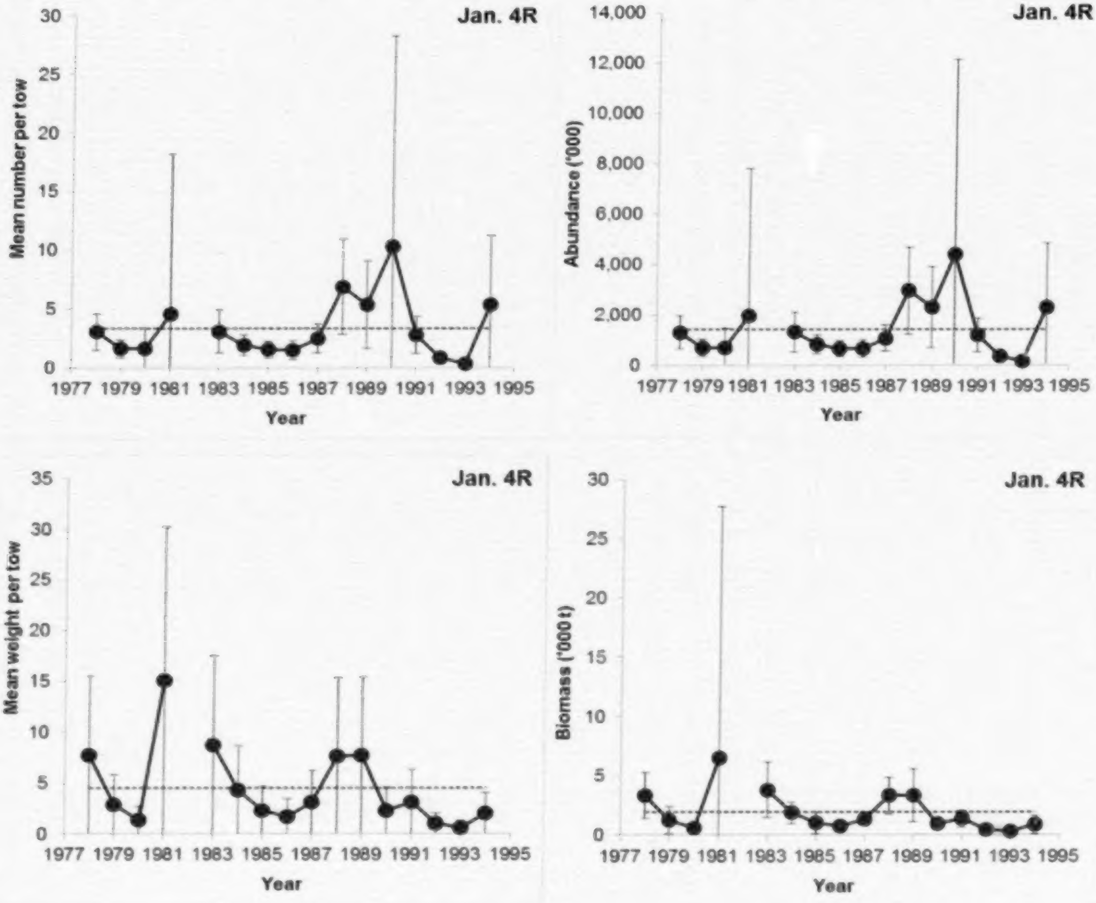


Figure 75. Common Lumpfish abundance (mean number per tow and total abundance) and biomass (mean weight in kg per tow and total biomass) indices in Div. 4R in DFO-QC January Engel survey, 1978-94. Vertical lines represent ± 95% confidence intervals, and dashed lines represent the average of the series.

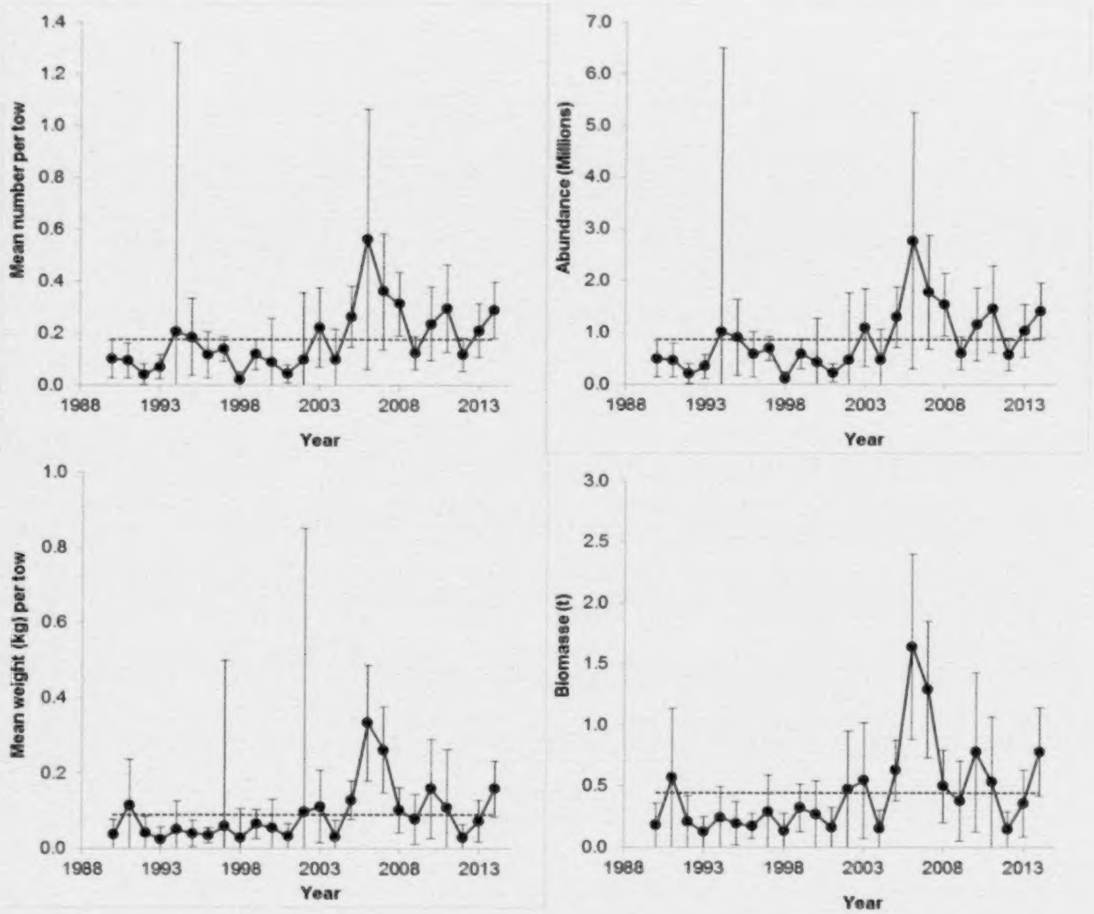


Figure 76. Common Lumpfish abundance (mean number per tow and total abundance) and biomass (mean weight in kg per tow and total biomass) indices in DFO-QC summer survey of Divs. 4RST, 1990-2014. Error bars represent 95% confidence intervals, and dashed horizontal lines indicate the mean for this time period.

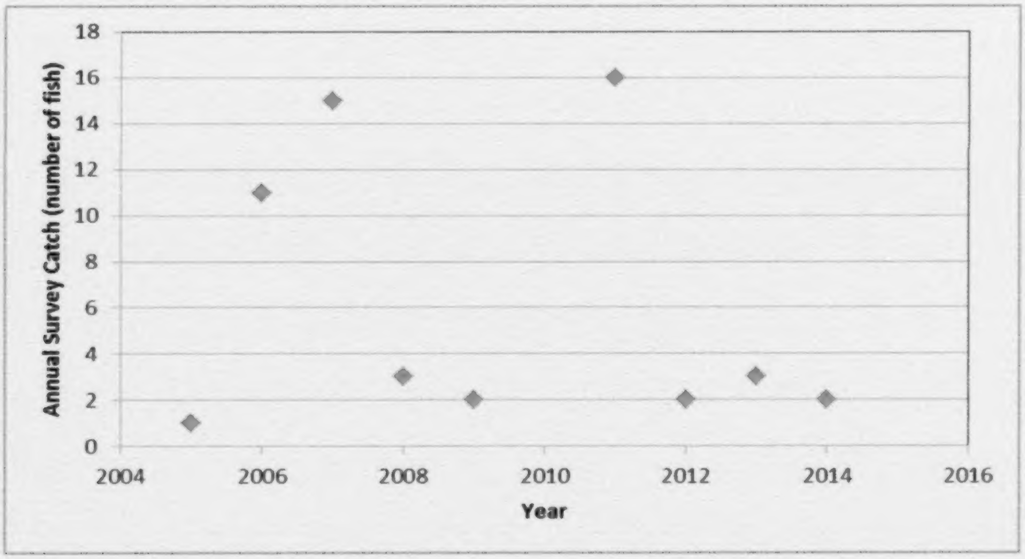


Figure 77. Total number of Common Lumpfish caught in DFO and Northern Shrimp Research Foundation bottom trawl surveys of Subarea 0, 2005-14.

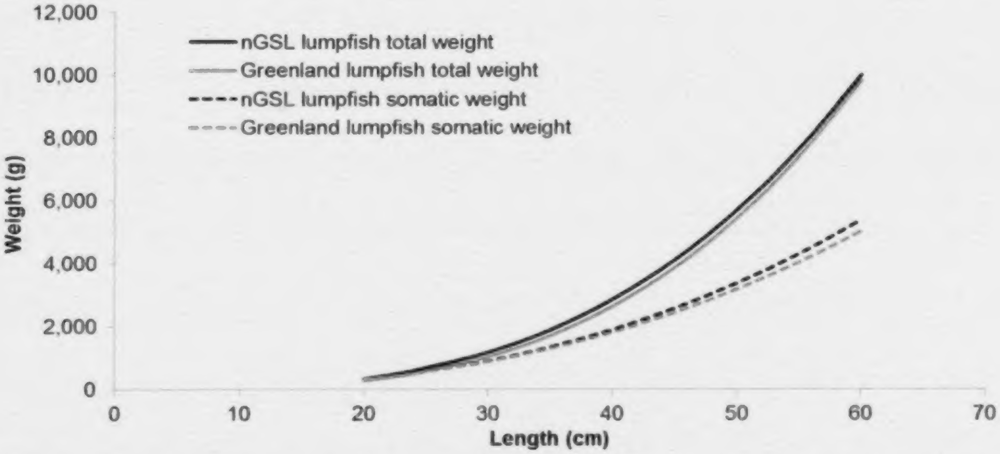


Figure 78. Length-weight relationships for Common Lumpfish from Canadian (specifically, northern Gulf of St. Lawrence - nGSL) and west Greenland studies.

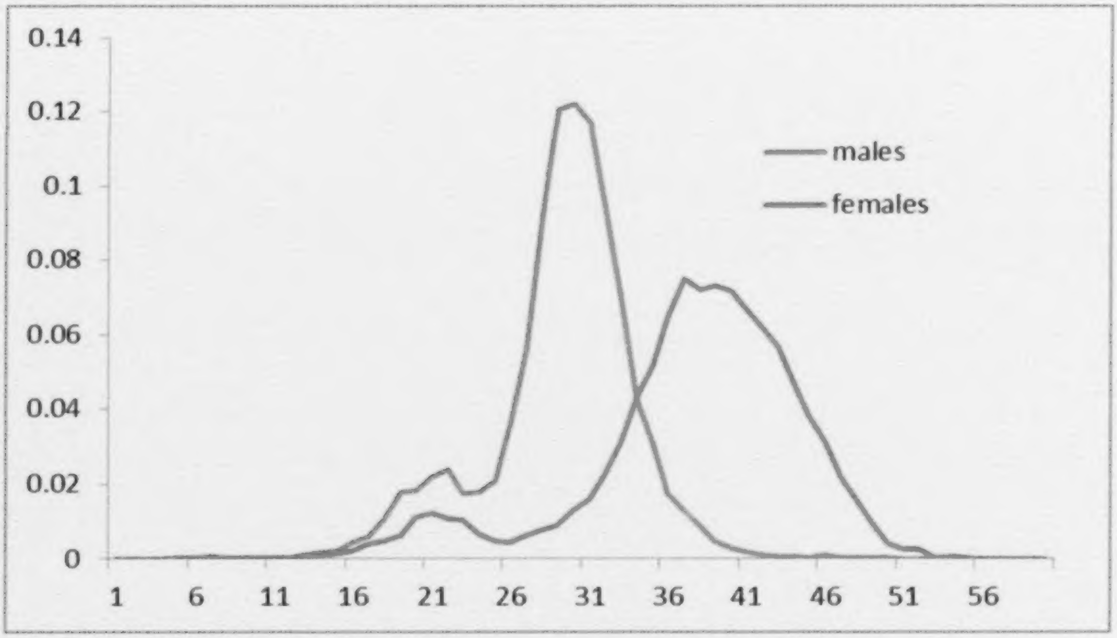


Figure 79. Length distribution of Common Lumpfish from DFO-NL spring surveys in Divs. 3LNOPs, 1984-2014.

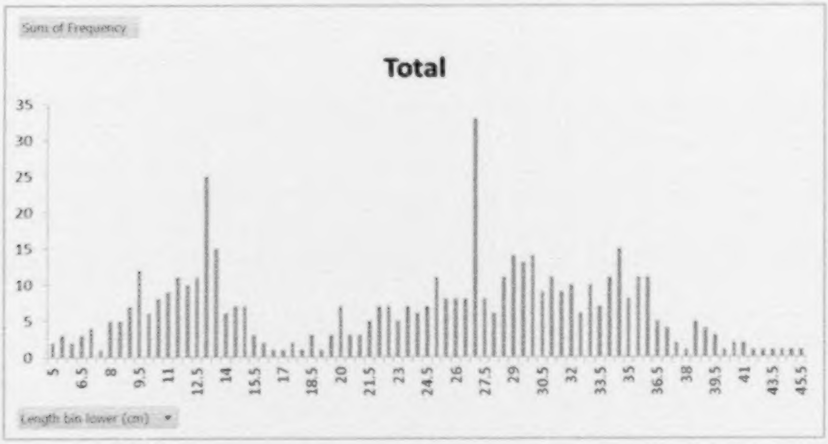


Figure 80. Length distribution of Common Lumpfish (sexes combined) from the Canadian pelagic survey, 2008-09.

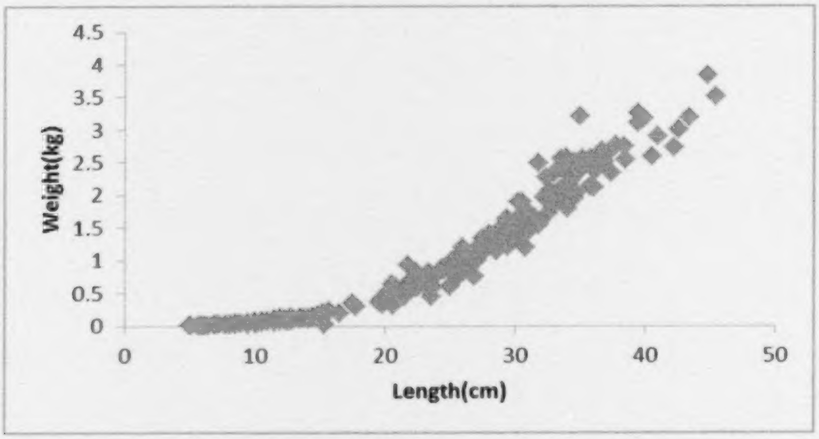


Figure 81. Length-weight relationship of Common Lumpfish from the Canadian pelagic survey, 2008-09.

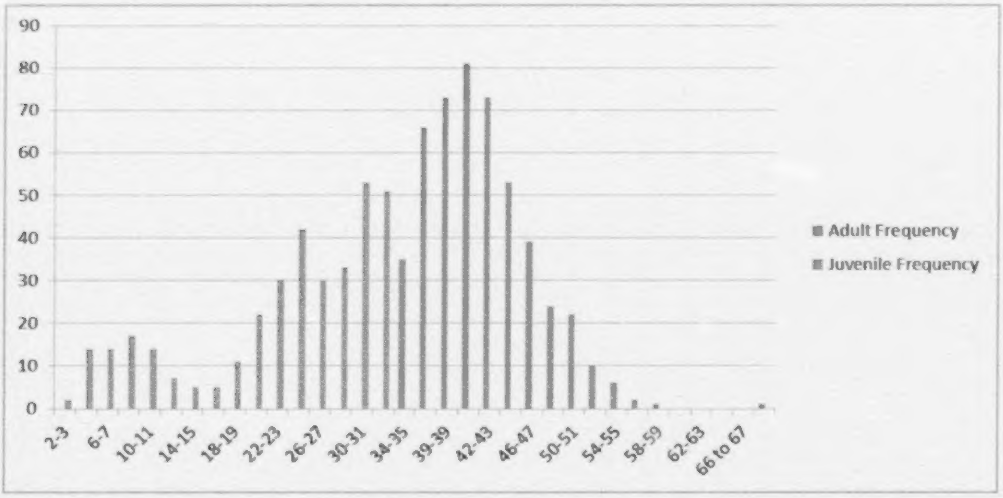


Figure 82. Length distribution of adult and juvenile Common Lumpfish (sexes combined) from all DFO-MAR research surveys, combined.

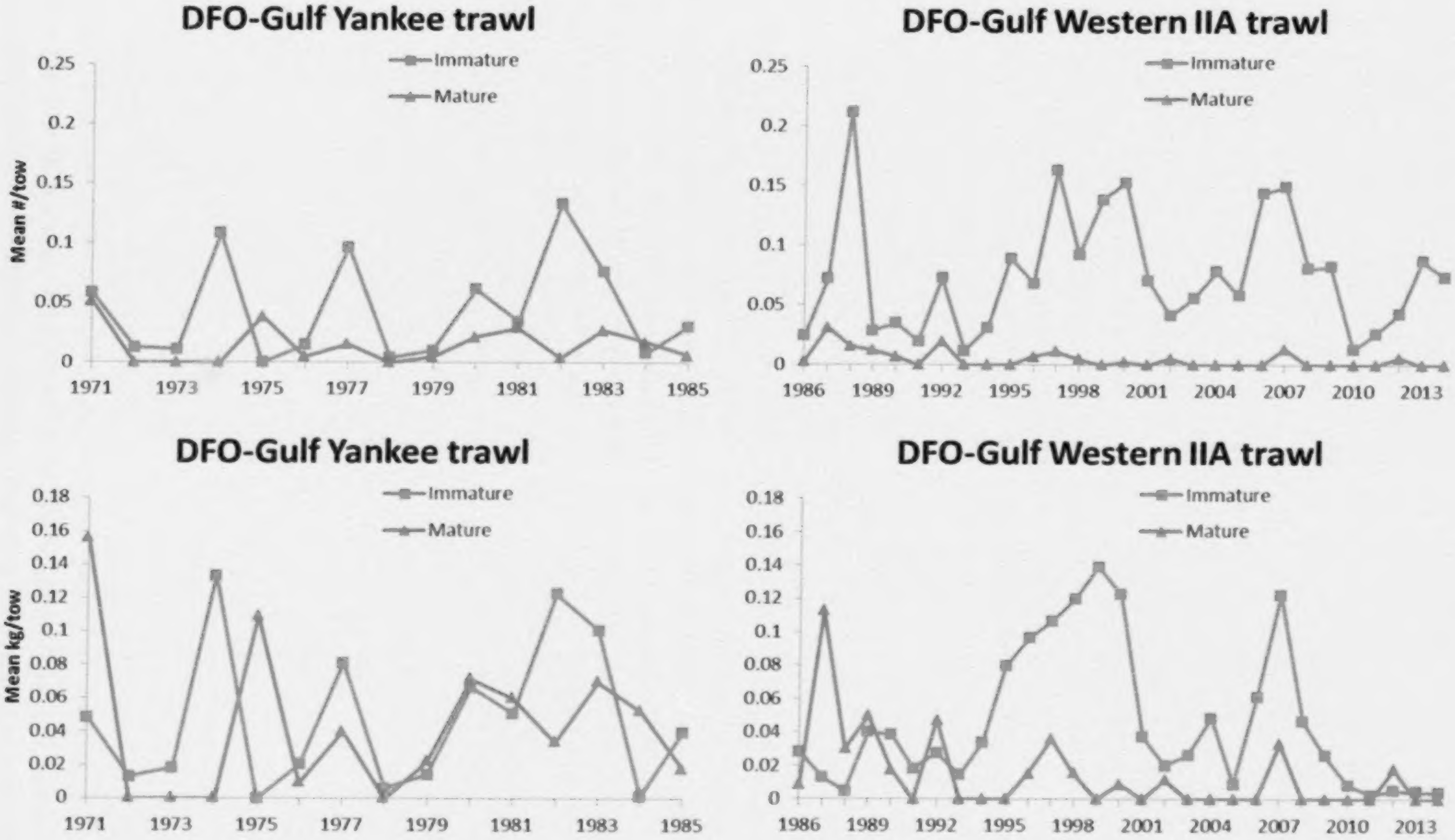


Figure 83. Abundance and biomass indices for mature and immature Common Lumpfish in DFO-Gulf research surveys of Div. 4T, 1971-2014.

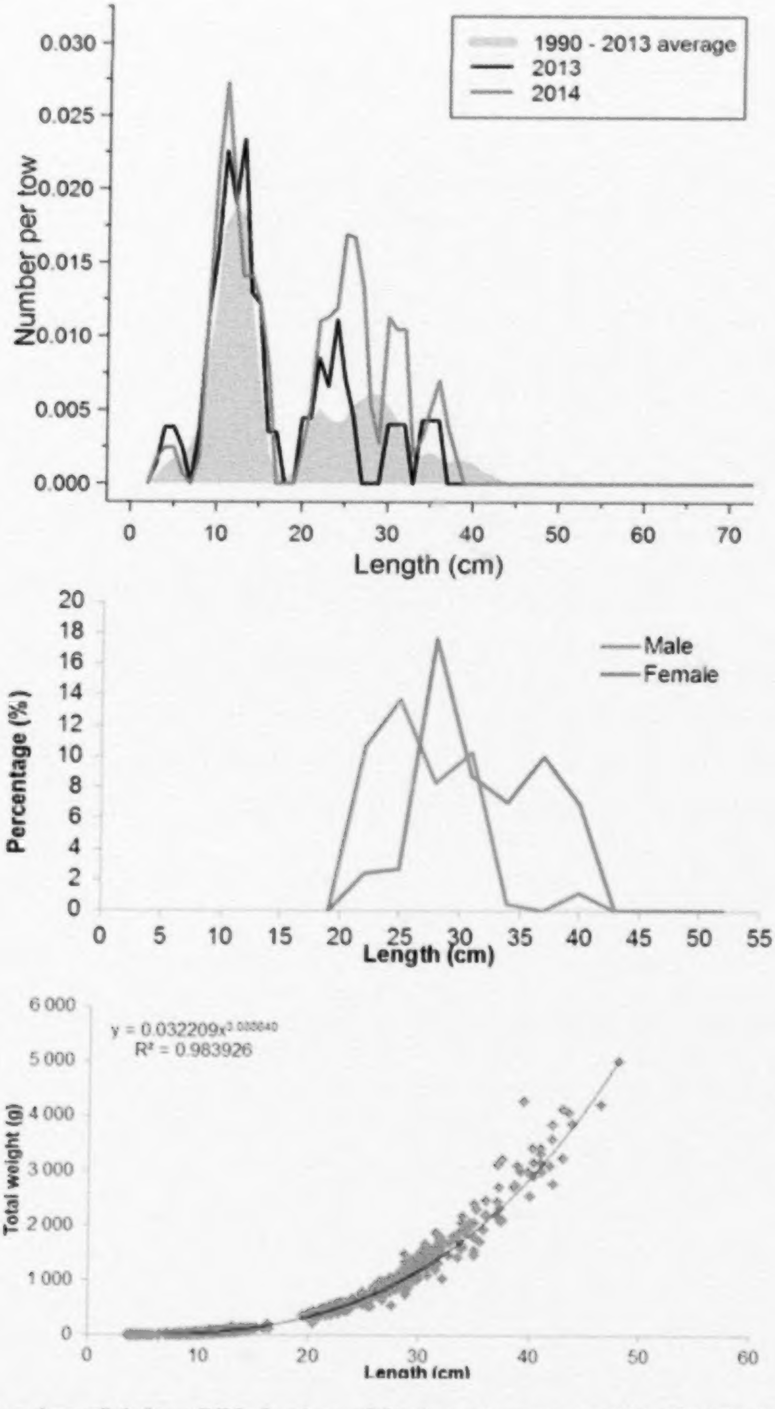


Figure 84. Common Lumpfish from DFO-Quebec nGSL August survey in 1990-2014 (Teleost-Campelen equivalent units): length distributions (mean number per tow; sexes combined; top panel); length distribution by sex for lumpfish ≥ 19 cm (middle panel); and length-weight relationship (bottom panel).

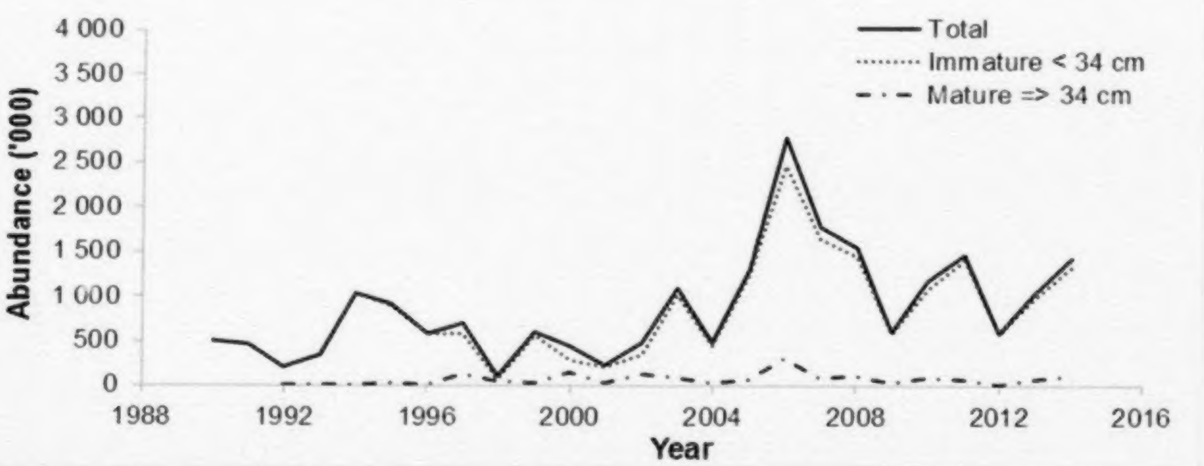


Figure 85. Minimum trawlable abundance of Common Lumpfish for total, mature, and immature populations in Divs. 4RST on DFO-Quebec nGSL August surveys (immature <34 cm, mature ≥34 cm).

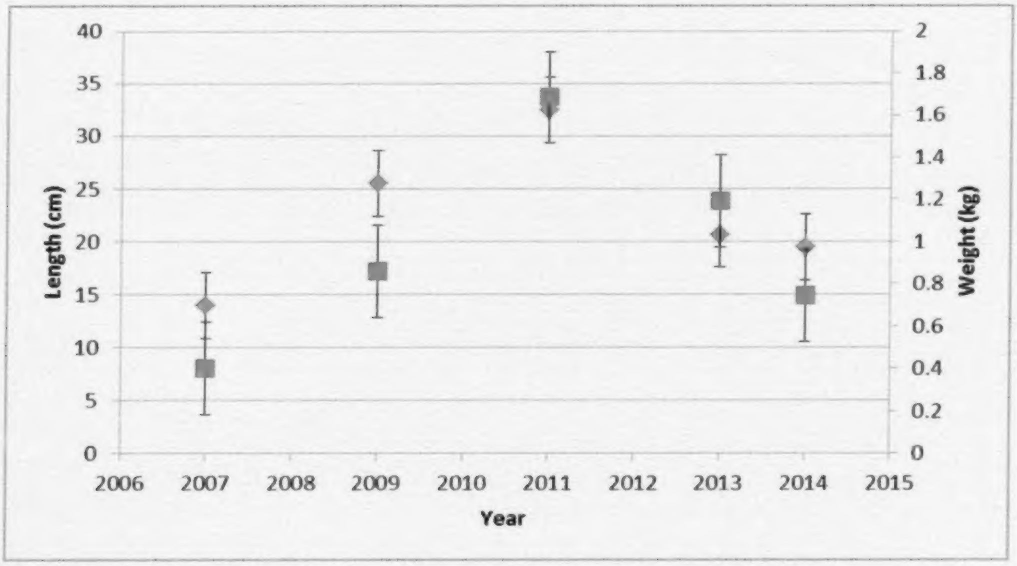


Figure 86. Mean fish length (blue diamonds) and weight (red squares) for Common Lumpfish caught in DFO and Northern Shrimp Research Foundation bottom trawl surveys of SA 0, 2007-14. Error bars indicate one standard error.

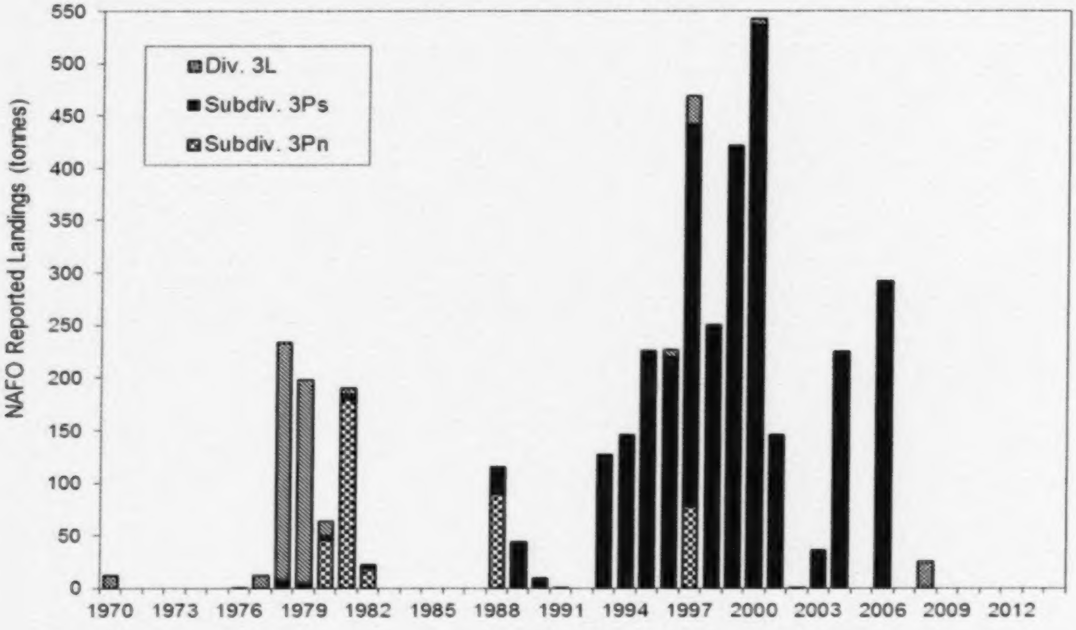


Figure 87. NAFO-reported landings (tonnes; STATLANT-21A) of Common Lumpfish by member countries in Divs. 3LP, 1970-2014.

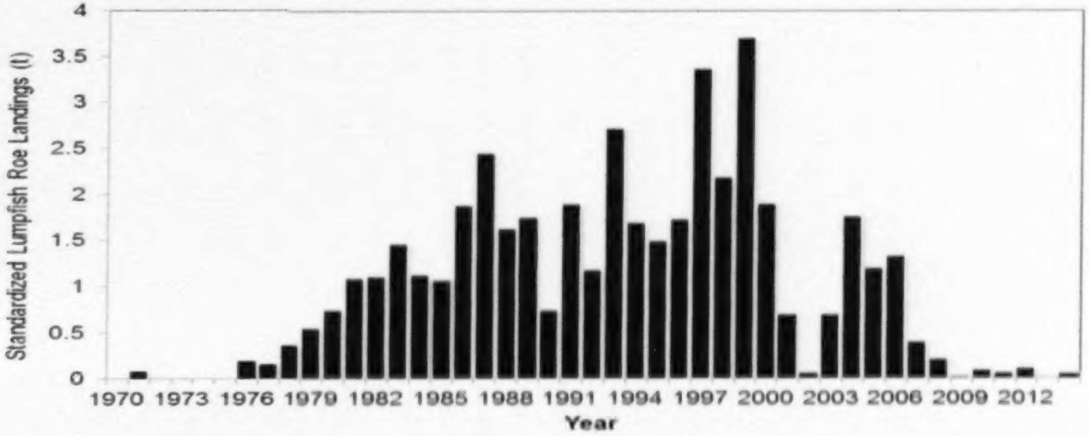


Figure 88. Standardized Common lumpfish roe landings (t) from Divs. 4RS3P, 1970-2014.

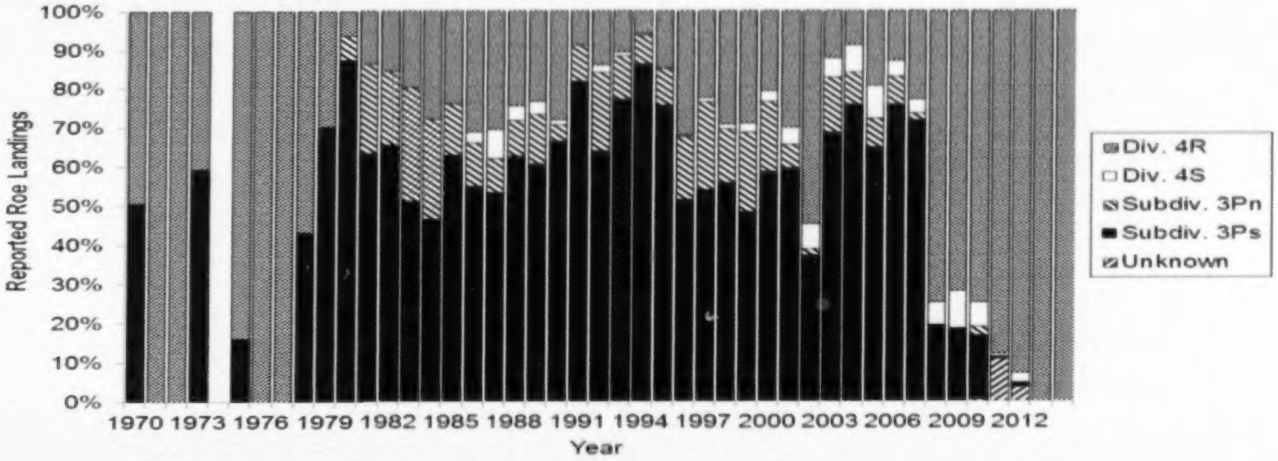


Figure 89. Proportion of Common Lumpfish roe landings from Divs. 4RS3P, 1970-2014.

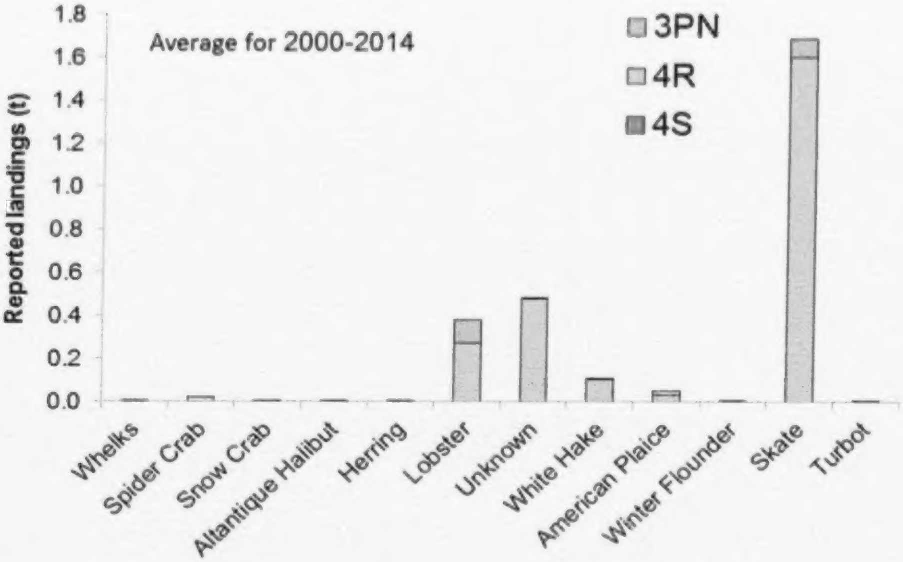


Figure 90. Average annual reported landings of Common Lumpfish roe from Subdiv. 3Pn and Divs. 4RS, by directed species, from 2000-14.

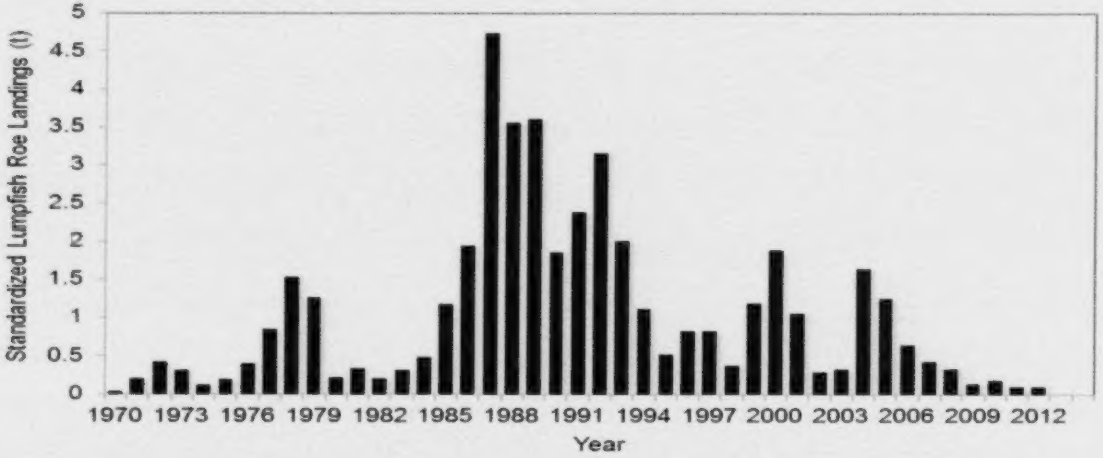


Figure 91. Standardized Common Lumpfish roe landings (t) from Divs. 2J3KL, 1970-2014.

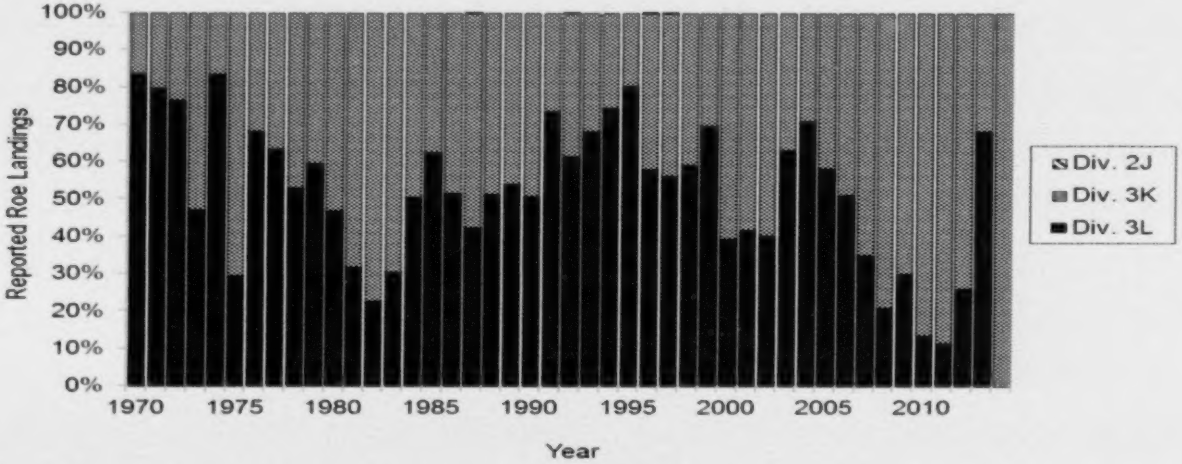


Figure 92. Proportion of Common Lumpfish roe landings from Divs. 2J3KL, 1970-2014.

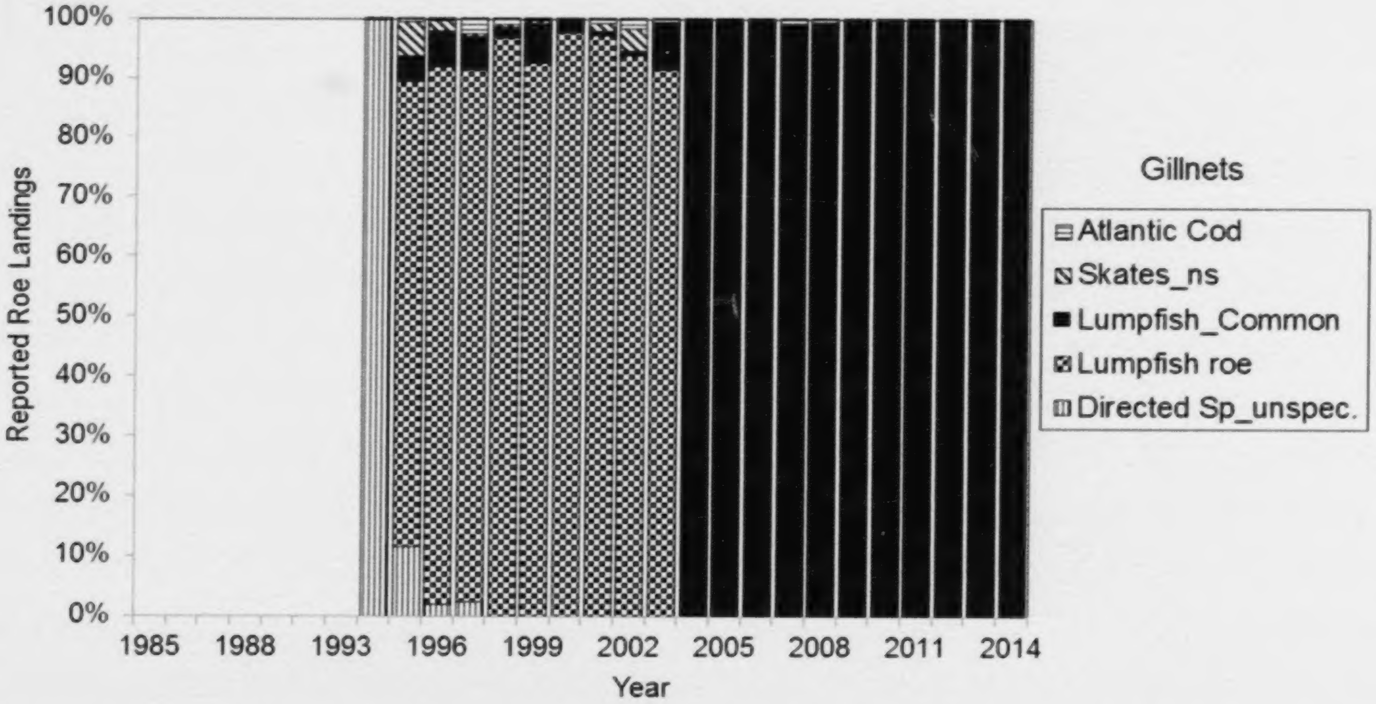


Figure 93. Proportion of Common Lumpfish roe landings from gillnets in Divs. 3KLOP by directed species, 1985-2014.

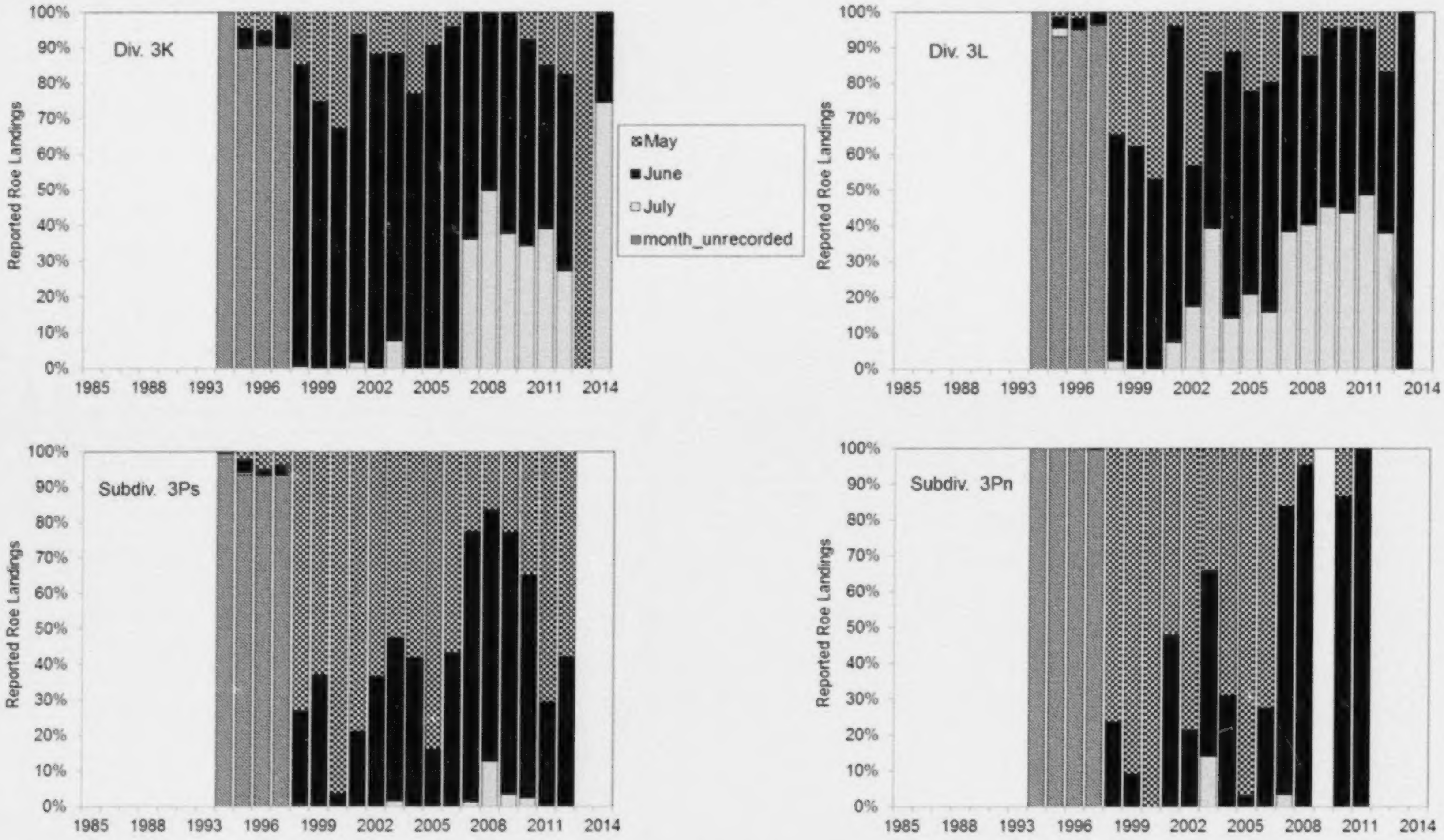


Figure 94. Proportion of Common Lumpfish roe landings from Divs. 3KLOP by month, 1985-2014.

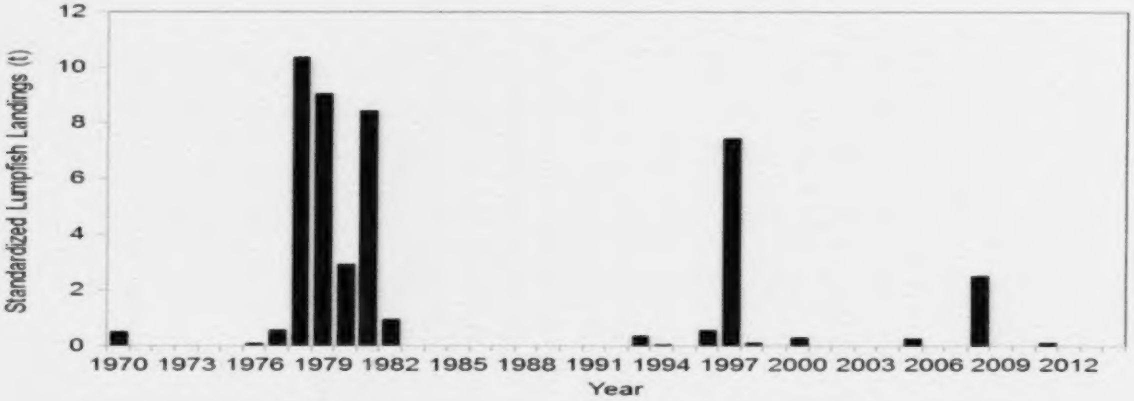


Figure 95. Standardized Common Lumpfish landings (t) from Divs. 3KLOP, 4R, and 5Y, 1970-2014.

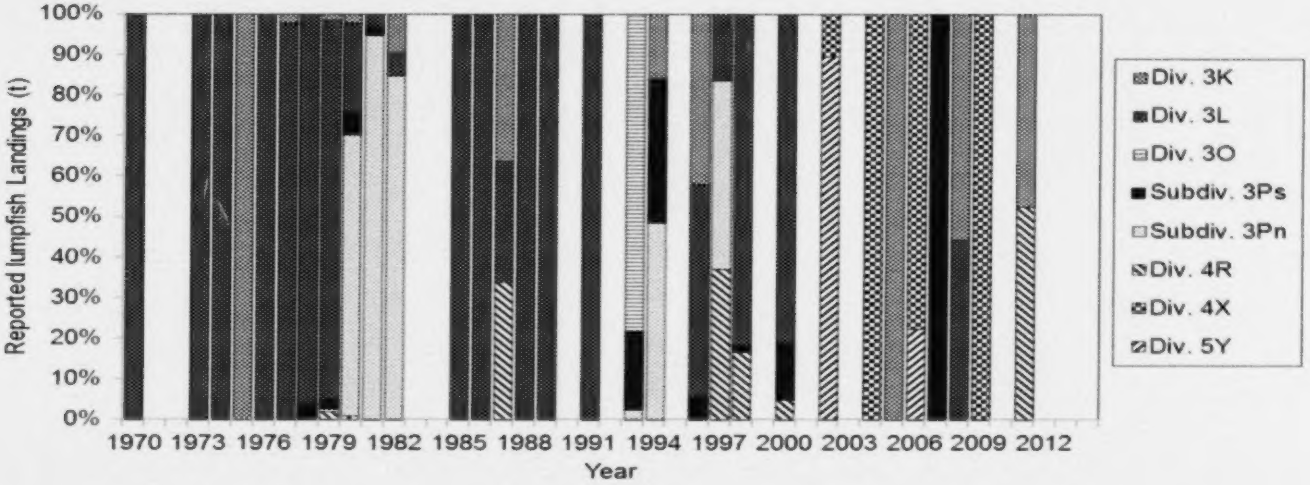


Figure 96. Proportion of Common Lumpfish landings from Divs. 3-5, 1970-2014.

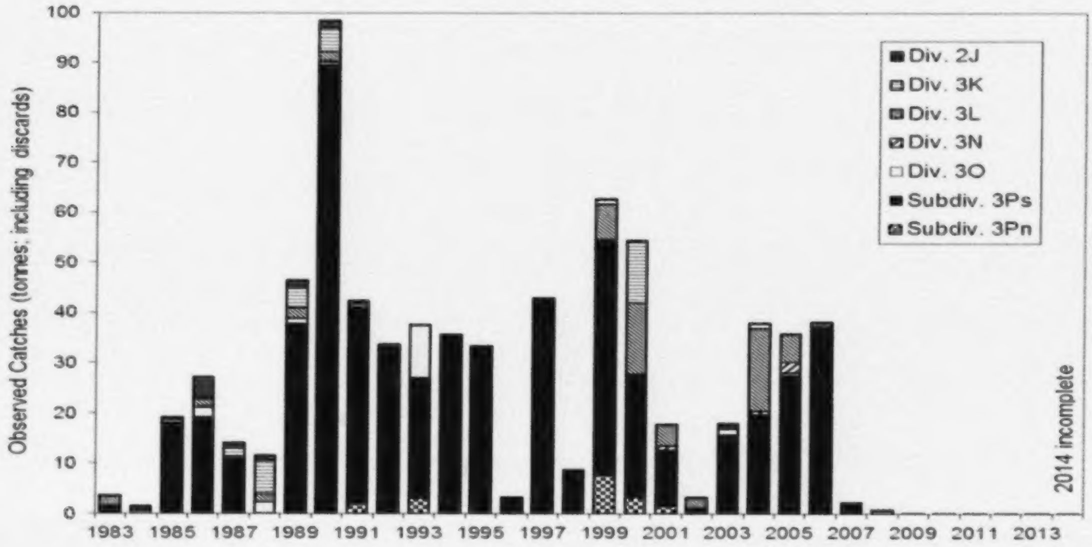


Figure 97. Observed catches (t) of Common Lumpfish in various fisheries in Canada's EEZ of Divs. 2J3KLNOP, 1983-2014. Data are from Canadian At-Sea Fisheries Observers, and include discards.

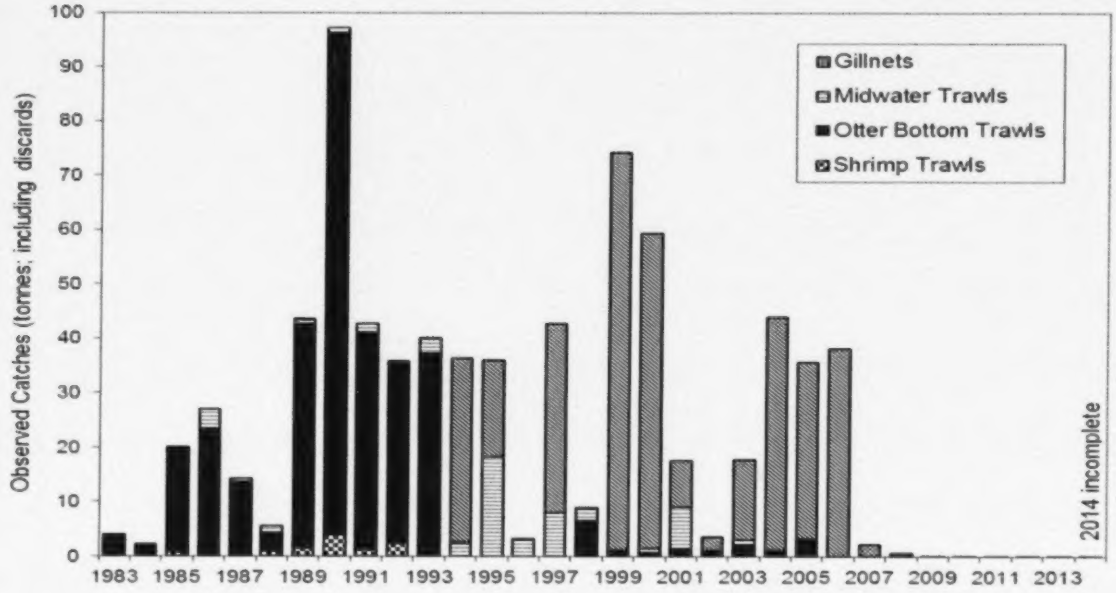


Figure 98. Observed catches (t) of Common Lumpfish by gear type in Canada's EEZ of Divs. 2J3KLNOP, 1983-2014. Data are from Canadian At-Sea Fisheries Observers, and include discards.

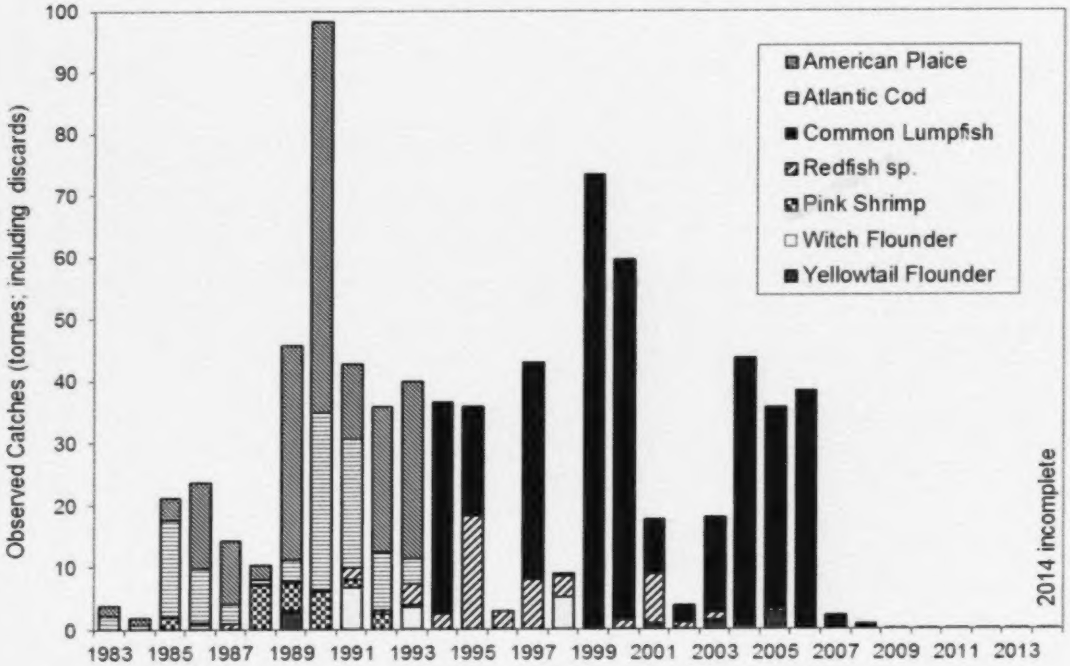


Figure 99. Observed catches (t) of Common Lumpfish by directed species in Canada's EEZ of Divs. 2J3KLNOP, 1983-2014. Data are from Canadian At-Sea Fisheries Observers, and include discards.

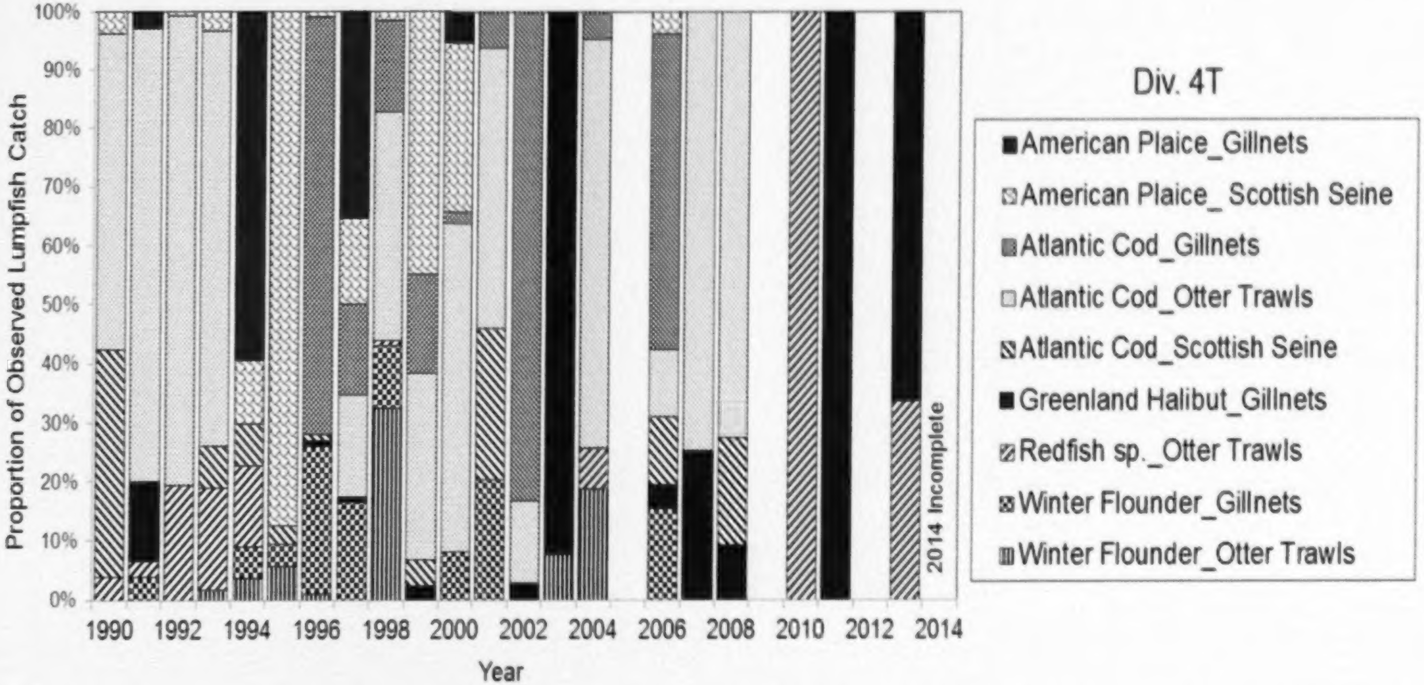


Figure 100. Proportion of observed catches of Common Lumpfish by directed species in Div. 4T, 1990-2014. Data are from Canadian At-Sea Fisheries Observers, and include discards.

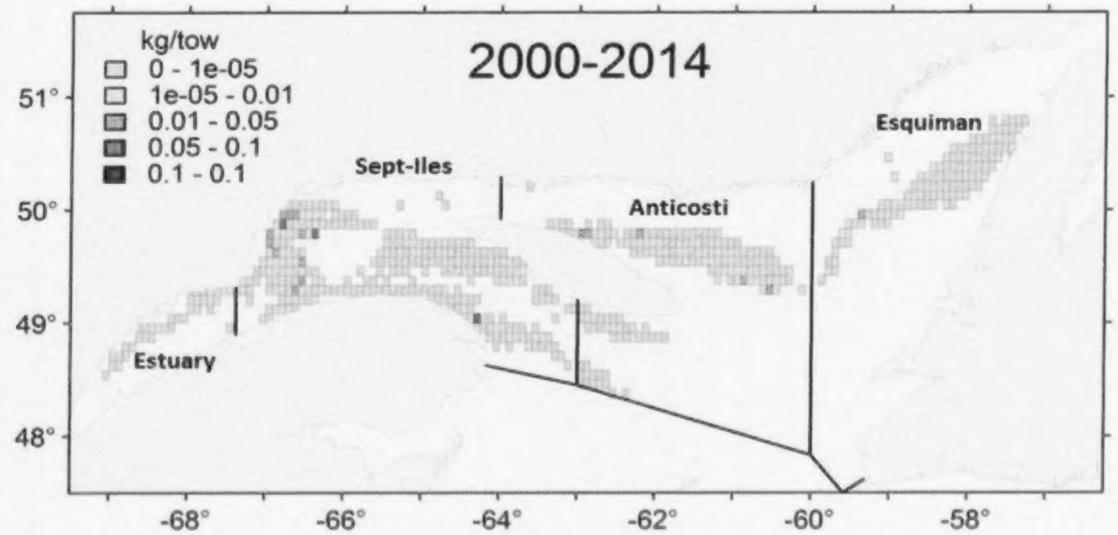

kg/tow
0 - 1e-05
1e-05 - 0.01
0.01 - 0.05
0.05 - 0.1
0.1 - 0.1
2000-2014
Esquiman
Sept-Iles
Anticosti
Estuary
51°
50°
49°
48°
-68°
-66°
-64°
-62°
-60°
-58°

Figure 101. Geographical distribution of mean catches of Common Lumpfish by statistical squares of 5 minutes during fishing activities directed on shrimp in the presence of a Canadian ASO.

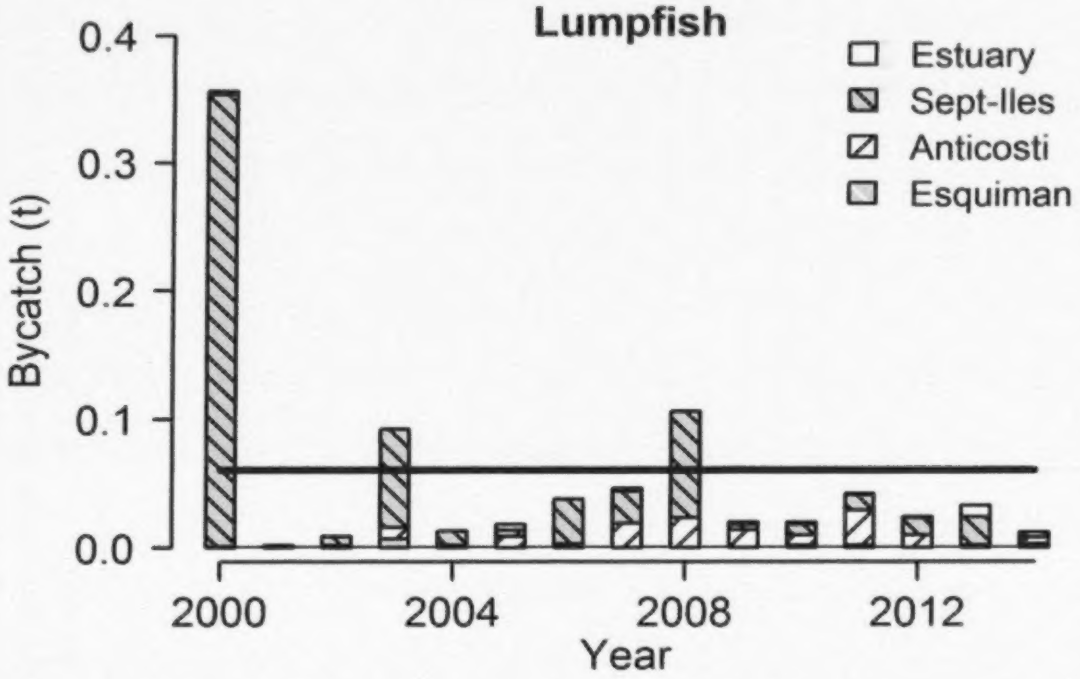


Figure 102. Annual bycatch of Common Lumpfish (reported per shrimp fishing area) estimated from Canadian ASO data. Solid black line indicates the average for 2000-13.

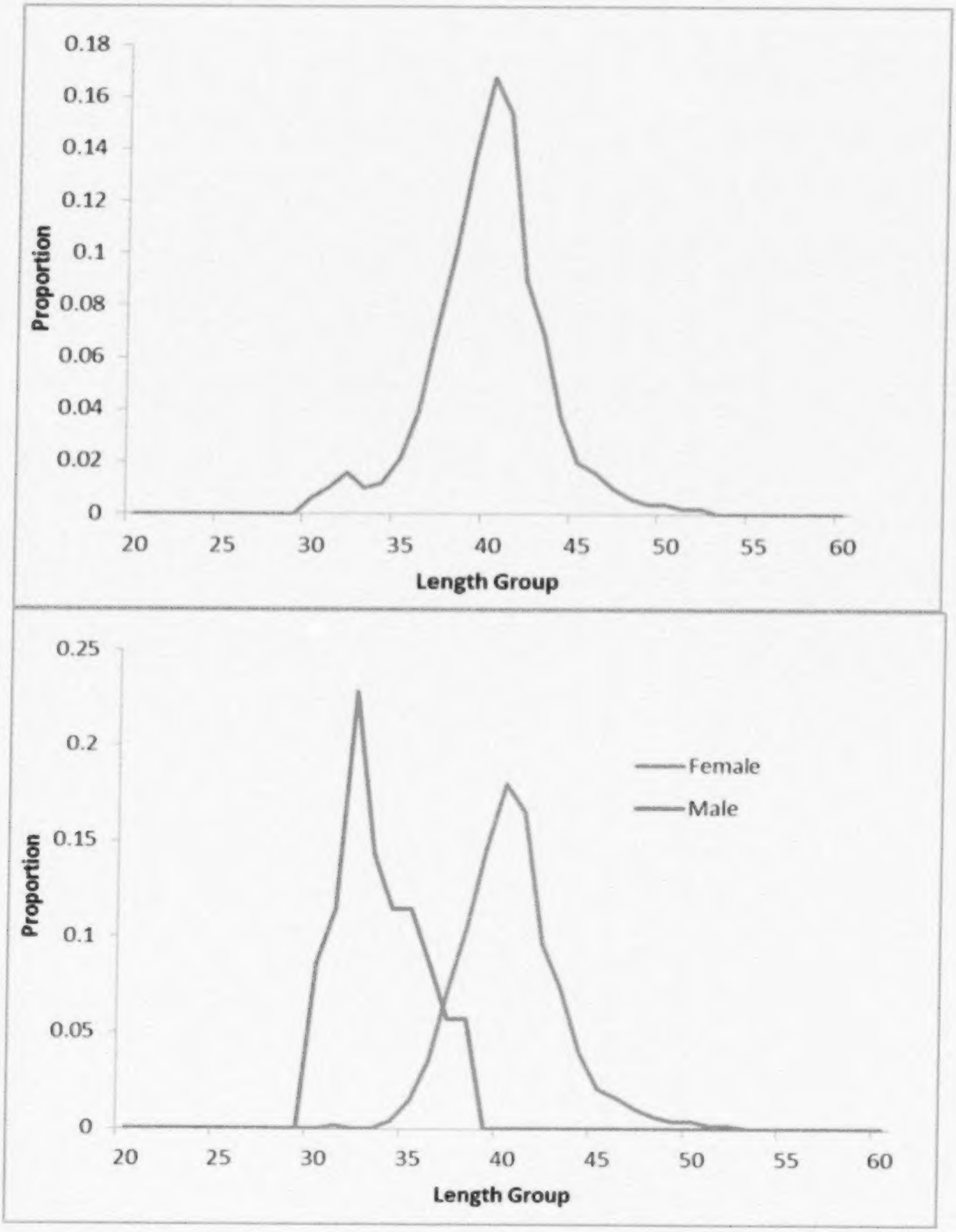


Figure 103. Observed sizes of Common Lumpfish in Subdiv. 3Ps gillnet fisheries over 1995-97: sexes combined (top panel); and separate (bottom panel). Data are from Canadian At-Sea Fisheries Observers, and include discards.

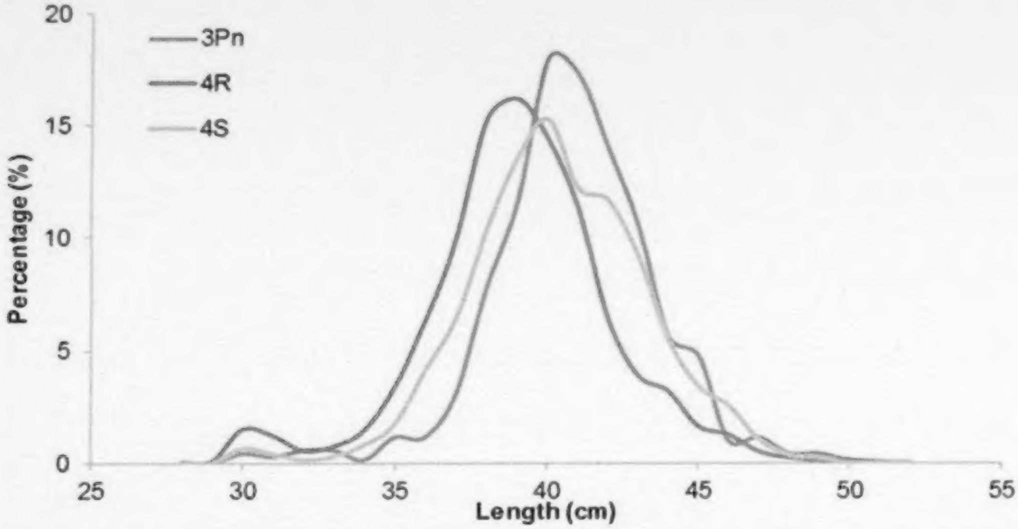


Figure 104. Observed sizes of Common Lumpfish in Subdiv. 3Pn and Divs. 4RS since 2004. Data are from DFO port samplers for Div. 4S (2006-12), and from the Fisheries Science Collaborative Program in the Divs. 4RS3Pn lumpfish-directed fishery (2004-08).

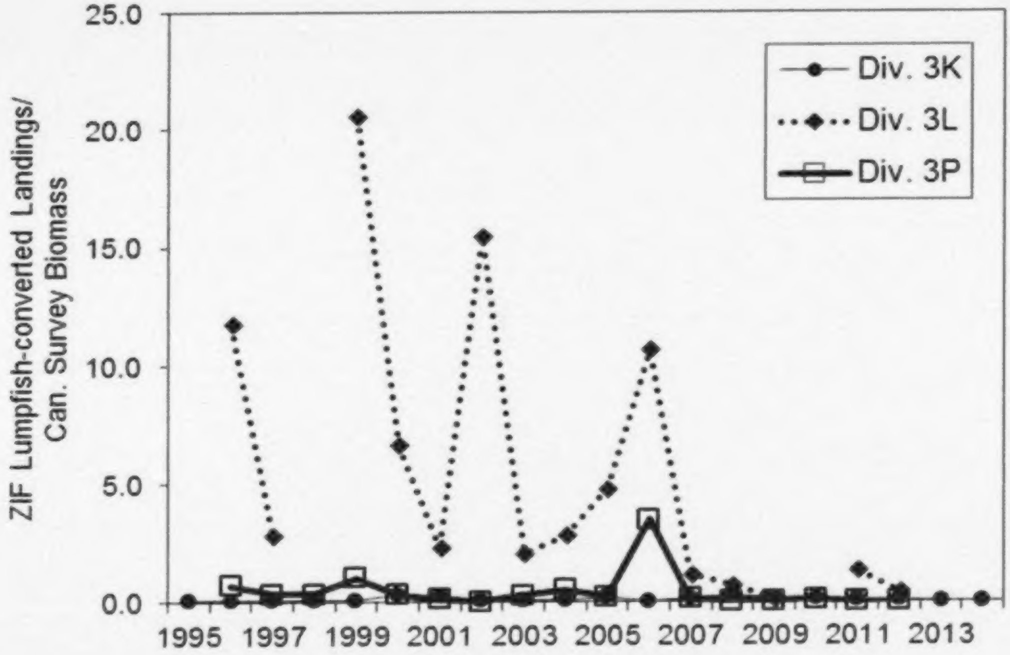


*Figure 105. Relative F index (=(ZIFF-reported landings of Common Lumpfish roe)*4/Canadian Campelen survey biomass) for Divs. 3KLP, 1996-2014. Note that fall biomass was used for Div. 3K (1995+), spring biomass for Divs. 3LP (1996+), and most of Subdiv. 3Ps was not surveyed in 2006.*

APPENDIX II - TABLES

Table 1. DFO spring research surveys conducted in Newfoundland and Labrador waters (Divs. 2GHJ3KLMNO and Subdiv. 3Ps) using: Yankee 41.5 otter trawl (Y) in 1971-83; Engel 145 otter trawl (E) in 1984-95; and Campelen 1800 shrimp trawl (C) in 1996-2014. Empty cell (-): no survey was conducted. Spring survey in 2006 was incomplete (INC); those data were not included in the analyses.

Year	Spring 3L	Spring 3N	Spring 3O	Spring 3Ps
1971	Y	Y	Y	-
1972	Y	Y	-	Y
1973	Y	Y	Y	Y
1974	Y	Y	-	Y
1975	Y	Y	Y	Y
1976	Y	Y	Y	Y
1977	Y	Y	Y	Y
1978	Y	Y	Y	Y
1979	Y	Y	Y	Y
1980	Y	Y	Y	Y
1981	Y	Y	Y	Y
1982	Y	Y	Y	Y
1983	-	-	-	E
1984	E	E	E	E
1985	E	E	E	E
1986	E	E	E	E
1987	E	E	E	E
1988	E	E	E	E
1989	E	E	E	E
1990	E	E	E	E
1991	E	E	E	E
1992	E	E	E	E
1993	E	E	E	E
1994	E	E	E	E
1995	E	E	E	E
1996	C	C	C	C
1997	C	C	C	C
1998	C	C	C	C
1999	C	C	C	C
2000	C	C	C	C
2001	C	C	C	C
2002	C	C	C	C
2003	C	C	C	C
2004	C	C	C	C
2005	C	C	C	C
2006	INC	INC	INC	-
2007	C	C	C	C
2008	C	C	C	C
2009	C	C	C	C
2010	C	C	C	C
2011	C	C	C	C
2012	C	C	C	C
2013	C	C	C	C
2014	C	C	C	C

Table 2. DFO fall research surveys conducted in Newfoundland and Labrador waters (Divs. 2GHJ3KLMNO) using: Engel 145 otter trawl (E) in 1977-94; and Campelen 1800 shrimp trawl (C) in 1995-2014. Empty cell (-): no survey was conducted.

Year	Fall 2G	Fall 2H	Fall 2J	Fall 3K	Fall 3L	Fall 3M	Fall 3N	Fall 3O
1971	-	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-
1977	-	-	E	E	-	Y	-	-
1978	E	E	E	E	-	E	-	-
1979	E	E	E	E	-	E	-	-
1980	-	-	E	E	-	E	-	-
1981	E	E	E	E	E	E	-	-
1982	-	-	E	E	E	E	-	-
1983	-	-	E	E	E	E	-	-
1984	-	-	E	E	E	E	-	-
1985	-	-	E	E	E	E	-	-
1986	-	-	E	E	E	-	-	-
1987	E	E	E	E	E	-	-	-
1988	E	E	E	E	E	-	-	-
1989	-	-	E	E	E	-	-	-
1990	-	-	E	E	E	-	E	E
1991	E	E	E	E	E	-	E	E
1992	-	-	E	E	E	-	E	E
1993	-	-	E	E	E	-	E	E
1994	-	-	E	E	E	-	E	E
1995	-	-	C	C	C	-	C	C
1996	C	C	C	C	C	C	C	C
1997	C	C	C	C	C	C	C	C
1998	C	C	C	C	C	C	C	C
1999	C	C	C	C	C	C	C	C
2000	-	-	C	C	C	C	C	C
2001	-	C	C	C	C	C	C	C
2002	-	-	C	C	C	C	C	C
2003	-	-	C	C	C	C	C	C
2004	-	C	C	C	C	-	C	C
2005	-	-	C	C	C	-	C	C
2006	-	C	C	C	C	C	C	C
2007	-	-	C	C	C	C	C	C
2008	-	C	C	C	C	-	C	C
2009	-	-	C	C	C	-	C	C
2010	-	C	C	C	C	-	C	C
2011	-	C	C	C	C	-	C	C
2012	-	C	C	C	C	-	C	C
2013	-	C	C	C	C	-	C	C
2014	-	C	C	C	C	-	INC	-

Table 3. DFO-QC research surveys conducted in the northern Gulf of St. Lawrence, 1978-2014.

Surveys	Vessel	Vessel Size (m)	Year	Month	Gear	NAFO	Coverage	Tow duration (min)	Tow speed (knots)	Wing spread (ft)
DFO - Winter	Gadus Atlantica	73.8	1978-1994 No survey in 1982	Jan.	Engels 145 Hi-Lift Codend liiner mesh size:30 mm	3Pn, 4RST	Strata >50 fathoms Estuary not covered Average area: 31,700-100,400 km^2 3Pn and 4R well covered	30	3.5	45
DFO - Summer	Alfred Needler	50.3	1990-2005 No survey in 2004	Aug.	URI shrimp trawl 81'/114' Codend liner mesh size:19 mm	3Pn, 4RST	Addition of shallow strata: 20-50 fathoms 3Pn covered from 1993 -2003 Area 95,070 – 119,000 km^2	24	3	44
-	Teleost	63	2004-2014	Aug.	Campelen 1800 Rock Hopper foot gear Codend liner mesh size: 12.7 mm	4RST	3Pn is no longer covered Average area: 114,482 km^2 Addition in 2008 4 new strata In the Estuary, 37-183 m	15	3	55.6
Industry	Sentinel commercial boats from QC and NL regions	13.72-19.81	1995-2014	July	Star Balloon 300 Rock Hopper foot gear Codend liner mesh size: 40 mm Restrictor cable	3Pn, 4RST	Estuary not covered Average area: 114,482 km^2 Range: 109,008-117,449 km^2	30	2.5	54

Table 4. Individual measurements and environmental conditions at site of capture for twelve Common Lumpfish caught between 2007 and 2014.

Year	**Date**	**Weight (kg)**	**Length (cm)**	**Depth**	**Temp_(C)**	**Salinity**
2007	15/10/2007	0.022	7.5	169.93	0.036	33
2007	19/10/2007	0.014	6.5	227.23	-0.894	33
2007	23/10/2007	1.174	28	225.26	-0.173	33
2009	21/10/2009	0.63	23	135.71	-0.16	33
2009	21/10/2009	1.086	28	172.98	-0.12	33
2011	08/10/2011	1.67	32	910.97	3.36	34
2011	10/10/2011	1.699	33	1236.17	3.71	35
2013	28/09/2013	3.446	41	474.27	4.21	35
2013	13/10/2013	0.036	9	1124.53	3.88	35
2013	13/10/2013	0.096	12	1220.28	3.81	35
2014	14/10/2014	0.057	10	942.65	4.06	35
2014	15/10/2014	1.435	29	415.47	2.38	34

Table 5. NAFO-reported landings (tonnes; STATLANT-21A) of Common Lumpfish by Division in 1970-2014.

Year	Div. 3K	Div. 3L	Div. 3M	Div. 3N	Div. 3O	Subdiv. 3Ps	Subdiv. 3Pn
1970	-	13	-	-	-	-	-
1971	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-
1976	-	2	-	-	-	-	-
1977	-	13	-	-	-	-	-
1978	-	225	-	-	-	9	-
1979	3	192	-	-	-	4	2
1980	2	14	-	-	-	4	46
1981	-	6	-	-	-	4	180
1982	2	1	-	-	-	3	18
1983	-	-	-	-	-	-	-
1984	-	-	-	-	-	-	-
1985	-	-	-	-	-	-	-
1986	-	-	-	-	-	-	-
1987	-	-	-	-	-	-	-
1988	-	-	-	-	-	25	90
1989	-	-	-	-	-	44	-
1990	-	-	-	-	-	10	-
1991	-	1	-	-	-	-	-
1992	-	-	-	-	-	-	-
1993	-	-	-	-	-	127	-
1994	-	-	-	-	-	145	1
1995	-	-	-	-	-	226	-
1996	6	7	-	-	-	220	-
1997	-	27	-	-	-	364	78
1998	-	2	-	-	-	249	-
1999	-	-	-	-	-	422	-
2000	-	6	-	-	-	537	-
2001	-	-	-	-	-	146	-
2002	-	-	-	-	-	3	-
2003	-	-	-	-	-	36	-
2004	-	-	-	-	-	225	-
2005	6	-	-	-	-	-	-
2006	-	-	-	-	-	292	-
2007	-	-	-	-	-	-	-
2008	32	25	-	-	-	-	-
2009	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-
2011	1	-	-	-	-	-	-
2012	-	-	-	-	-	-	-
2013	-	-	-	-	-	-	-
2014	-	-	-	-	-	-	-

Table 6. Observed catches (mt) of Common Lumpfish by directed species in Maritimes Region commercial fisheries. Data are from DFO-MAR At-Sea Fisheries Observer database, and include discards.

Fishery	Number of sets observed with lumpfish	Total weight of lumpfish (mt)
AMERICAN LOBSTER	17	18.59
AMERICAN PLAICE	150	30616
BIGEYE TUNA	1	2
COD (ATLANTIC)	5766	197243
COD, HADDOCK, POLLOCK	129	300
HADDOCK	395	9334
HALIBUT (ATLANTIC)	48	3018
HERRING (ATLANTIC)	4	35
LONGHORN SCULPIN	106	271
MACKEREL (ATLANTIC)	5	20
MONKFISH,GOOSEFISH,ANGLER	17	43
OTHER	913	110248
PANDALUS BOREALIS	508	2023
PANDALUS MONTAGUI	108	278
PANDALUS SP.	1	10
POLLOCK	656	13458
REDFISH UNSEPARATED	2479	62315
SEA SCALLOP	25	197
SEA URCHINS	2	2
SHORT-FIN SQUID	3	13
SILVER HAKE	116	505
SKATES (NS)	19	52
SNOW CRAB (QUEEN)	140	19
TURBOT,GREENLAND HALIBUT	17	67
WHITE HAKE	10	36
WINTER FLOUNDER	52	173
WINTER SKATE	11	42
WITCH FLOUNDER	33	744
YELLOWTAIL FLOUNDER	62	759

APPENDIX III

Potential Sources of Mortality /Harm Permitted and Un-permitted Activities	**Source (with examples)**	**Proportion of Lumpfish Affected: LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN**	**Cause/ Time Frame** **Historic (H)** **Current (C)** **Potential (P)**	**Effect on Population: (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)**	**Management Alternatives/ Mitigation (*relative to existing actions*)**
Fishing Threats	Commercial (domestic) directed fishing	**UNCERTAIN**	HCP	**UNCERTAIN**	Reductions in fisheries
Fishing Threats	International High-seas (i.e., St.Pierre – Miquelon) directed fishing	**UNCERTAIN**	HCP	**UNCERTAIN**	Reductions in fisheries
Fishing Threats	Recreational near-shore directed fishing	**UNCERTAIN**	P	**UNCERTAIN**	-
Fishing Threats	Exploratory/commercial fisheries for other species, both inshore and offshore	**UNCERTAIN**	HCP	**UNCERTAIN**	Reductions in fisheries
Fishing Threats	CUMULATIVE EFFECT	**UNCERTAIN**	HCP	**UNCERTAIN**	A 5-year Integrated Fisheries Management Plan.

Potential Sources of Mortality /Harm Permitted and Un-permitted Activities	Source (with examples)	Proportion of Lumpfish Affected: LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN	Cause/ Time Frame Historic (H) Current (C) Potential (P)	Effect on Population: (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)	Management Alternatives/ Mitigation (*relative to existing actions*)
Non-fishing threats	Municipal waste water treatment facilities and dumping	**UNCERTAIN**	HCP	**UNCERTAIN**	Ensure current projects and future developments meet standards.
Non-fishing threats	Urbanization (altered near-shore hydrology)	**UNCERTAIN**	HCP	**UNCERTAIN**	Ensure current projects and future developments meet standards.
Non-fishing threats	Aquaculture	**UNCERTAIN**	HCP	**UNCERTAIN**	Choose locations carefully, monitor, follow guidelines and best practices.
Non-fishing threats	Municipal, Provincial & Federal dredging	**UNCERTAIN**	HCP	**UNCERTAIN**	Ensure current projects and future projects meet standard.
Non-fishing threats	Marine Dumping	**UNCERTAIN**	HCP	**UNCERTAIN**	Ensure current projects and future projects meet standard.
Non-fishing threats	Climate change, changes in relative predator and prey abundances, disease.	**UNCERTAIN**	HCP	**UNCERTAIN**	-
Non-fishing threats	Oil development	**UNCERTAIN**	HCP	**UNCERTAIN**	Ensure current projects and future developments meet standards.
Non-fishing threats	Seismic	**UNCERTAIN**	HCP	**UNCERTAIN**	Ensure current projects and future developments meet standards.

APPENDIX IV

CONSERVATION HARVESTING PLAN (DFO-NL)
LUMPFISH
VESSELS LESS THAN 65 FEET
FIXED GEAR

NAFO Divisions 2J3KLP4R

This Conservation Harvesting Plan (CHP) applies to all vessels less than 65 feet in length, regardless of homeport, fishing Lumpfish in NAFO Divisions 2J3KLP4R effective 2013.

GENERAL PROVISIONS

A **fishing trip** will start from the time the fish harvester leaves port, and will end when the fish harvester returns to port for any reason, whether or not any fish is caught

FISHING GEAR

1. The only gear permitted to be used is gillnet having a minimum mesh size of 268 mm (10.5 inches).
2. The maximum number of gillnets permitted to be fished is 50 and each gillnet is not to exceed 50 fathoms in length.
3. Lost gillnets must be reported to the nearest DFO office within 72 hours, if the loss is noticed before the closure of a fishing area. If the fishing area is already closed, the loss must be reported within 24 hours.
4. Fish harvesters cannot fish with, nor have onboard their vessel, a groundfish gillnet unless a tag, issued under the authority of the Minister for the current year, is securely attached to the head-rope of the net in a manner for which the tag was designed.
5. The gillnet tag must be affixed to the head rope of each gillnet within 1.85 meters (6 feet) from the side rope on the end of the net where the float or buoy identifies the Vessel Registration number.

FISHING RESTRICTIONS

1. Fishing is authorized to be conducted in water depths less than 25 fathoms only.
2. Fishing for lumpfish is only permitted during the following period in the areas indicated:

2J3KL	**Opening**	**Closing**
2J Lodge Bay to Postville	May 28	July 15
Cape Bauld to Granite Point	May 21	July 8
Granite Point to Little Harbour Deep Head	May 28	July 15
Little Harbour Deep Head to Cape St. John	May 21	July 8
Cape St. John to North Head	June 4	July 22
North Head to Cape Freels	May 28	July 15
Bonavista Bay (north)	May 20	July 7
Bonavista Bay (south)	June 3	July 21
Trinity Bay	June 3	July 21
Conception Bay	June 3	July 21
Southern Shore	June 3	July 21
St. Mary's Bay	May 27	July 14
3Ps	**Opening**	**Closing**
Cape St. Mary's to Ship Harbour Point	May 14	July 1
Ship Harbour Point to Lawn Head	May 21	July 8
Lawn Head to Dantzic Point	May 9	June 26
Dantzic Point to Grand Bank Cape	May 9	June 26
Grand Bank Cape to Point Rosie	May 28	July 15
Point Rosie to Western Head (Hare Bay)	May 9	June 26
Western Head (Hare Bay) to Cinq Cerf in 3Pn	May 9	June 26
4R3Pn **subject to the 72 hour requirement**	**Opening**	**Closing**
Cinq Cerf to Cape Ray	May 9	June 26
Cape Ray to Johnson's Cove	Subject to test fishery	
Johnson's Cove to Cape St. George	Subject to test fishery	
Cape St. George to Cape St. Gregory	Subject to test fishery	
Cape St. Gregory to Point Riche	Subject to test fishery	
Point Riche to Cape Bauld	May 14	July 1
Quebec Border to Cape St. Charles	May 21	July 8

*Dates may be subject to in-season adjustments due to ice conditions.

In NAFO Division 4R, closures may be introduced on short notice if high levels of by-catch of Atlantic Halibut occur.

In NAFO Divisions 4R3Pn, the fishery will close 72 hours in advance of any opening of the commercial Cod fishery, and will not be considered for re-opening until 72 hours after the closure of the commercial Cod fishery.

To allow for the orderly management of the lumpfish fishery, openings will correspond with the beginning of the "fishing week," as defined as starting on Monday, unless seasonal conditions require that adjustments be made.

Fish harvesters are restricted to fishing the lumpfish area of their homeport unless they elect to fish in an alternate area.

Fish harvesters are permitted to change lumpfish areas only **ONCE** each year. This election must take place prior to the opening of the lumpfish season in the fisher's homeport area.

If a Fish harvester wishes to fish in a lumpfish area other than their homeport, they must contact the DFO Licensing Center **PRIOR** to the opening of the season in their homeport area and prior to the opening date of the area they intend to fish. Completion and submission of Schedule 14 is necessary to make this change.

MONITORING

1. Industry-funded at-sea observer coverage is required. The targeted level of coverage will be 5% of the fleet sector quota for observer coverage.
2. Although Lumpfish landings are not subject to dockside monitoring requirements, 100% of groundfish by-catch landed in the directed Lumpfish fishery is subject to comprehensive DMP. It is required that fishers contact a certified Dockside Monitoring Company to report any landings of groundfish by-catch and a dockside observer may be deployed to monitor the offloading or an authorization number will be provided to the fisher.

Test Fisheries

1. *If a fishery is closed due to incidental catch or small fish problems, it will not reopen until it can be effectively monitored and controlled.*
2. *Closures will be in effect for a minimum of 10 days.*
3. *If a fishery in a particular area is closed twice during the year, it may remain closed for the remainder of the year.*
4. *Where test fishing is conducted, a fishing plan will be developed which will include:*

- *areas to be tested*
- *quantity of gear to be used*
- *depth strata to be tested*
- *vessels to be used*
- *dates when test fishing will be carried out*
- *provision for at-sea observer coverage*

Test fishing will not commence until the fishing plan has been approved by DFO.

INCIDENTAL CATCH

For the purposes of this CHP, the following definitions apply:

"Directed species" means the permitted species, or combination of species, retained on board and taken by the fish harvester at a time, in an area and by a means that is authorized in species specific licence conditions.

"Incidental catch" means the catch retained on board of any species other than a directed species as defined above.

Unless otherwise stated, incidental catch restrictions are always expressed as daily limits (00:01 hours to 24:00 hours local time) calculated using round weights and are always calculated as a percentage of the round weight of the directed species retained onboard.

When fishing lumpfish in NAFO Divisions 2J3KL and sub-Division 3Ps, the following incidental catch provisions apply:

1. Unless otherwise specified below or in species specific provisions, incidental catch of cod may not exceed 10% or 200 pounds; whichever is greater.
2. When fishing in NAFO division 3L, the incidental catch of Redfish, American plaice and yellowtail flounder may not exceed 5%.

When fishing lumpfish in 4R3Pn, incidental catch of cod may not exceed 10%.

Where there are widespread incidental catch problems, an entire area may be closed to the fleet sector.

DISCARDING

1. In NAFO Divisions 2+3KLP, all Atlantic halibut less than 81 cm (or in NAFO Division 4R all Atlantic Halibut less than 85cm), and northern and spotted wolfish must be released to the place from which it was taken and, when alive, in a manner that causes the least harm.
2. Dogfish and lumpfish may be returned to the water immediately, dead or alive.
3. Live winter flounder less than 25cm and American plaice less than 20 cm in length may be returned to the water immediately.

OTHER

Other conservation measures may be identified and implemented during the year as required.

APPENDIX V

CONSERVATION HARVESTING PLAN (DFO-QC)

LUMPFISH

FIXED GEAR

SEASON 2014-2015

NAFO Division 4S

This conservation harvesting plan applies to ground fish licence holders within Quebec's region A-52 vessel class and directing their activity on lump fish in area 4S.

Species and Area

Lumpfish – 4S – Quebec Region

The access is limited to vessel class A-52 for the Quebec Region, gillnets in area 4S.

Management Measures

Fishing period:

June 13th 2014 to July 1st 2014

May 31st 2015 to July 1st, 2015

Fishing gear:

Authorized gear: Gillnet with a maximum length of 50 fathoms

Mesh size: Minimum mesh size of 267 mm (10 inches ½)

Number of nets: Maximum of 50 nets

Tagging:

All gillnets must be tagged with only one permanent valid tag before being put on the vessel for *transport to the fishing site.*

Combined form:

The logbook portion of the combined form must be completed daily.

Hail out:

Hail out is mandatory.

At sea observer:

At sea observer coverage is 10%.

Release of incidental catch:

You must return to the water immediately all Atlantic Halibut with a length less than 85 cm and all Skate and if the fish is alive, in a manner that causes it the least harm.

You are authorized to return to the water all Skate, Dogfish, Lumpfish, Sculpin, Atlantic Hagfish, and Striped Wolffish and if the fish is alive, in a manner that causes it the least harm.

Species at Risk Act

Pursuant to the Species at Risk Act (SARA), no person shall kill, harm, harass, capture, take, possess, collect, buy, sell or trade an individual or any part or derivate of a wildlife species designated as extirpated, endangered, or threatened. At the time this Management Plan is promulgated, the Gulf of St. Lawrence and the Atlantic species targeted by these measures are the following ones: Spotted Wolffish, Northern Wolffish, Leatherback Turtle, and Striped Bass (St. Lawrence Estuary population). New species could be added in the course of the year. All bycatch of species identified above must be returned to the water and released in the exact capture location and if the fish is still alive, in a manner that causes it the least harm. In addition,minformation regarding interactions with species at risk, including species mentioned above as well as the North Atlantic Right Whale, the Blue Whale (Atlantic population), and the Beluga Whale (St. Lawrence Estuary population) must be recorded in the Species At Risk section of the logbook.

Licence Conditions

To obtain your licence conditions, you must place your request through the National Online Licensing System (NOLS). Request will be treated within three working days. For any question *regarding NOLS, please phone our client service line at 1-877-535-7307.*